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Yang

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(54) MITIGATING SCRIPTED ATTACKS USING DYNAMIC POLYMORPHISM

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H04L 29/06 (2006.01)
G06F 21/54 (2013.01)

(52) **U.S. Cl.**
CPC ***H04L 63/168*** (2013.01); ***G06F 21/54*** (2013.01); ***H04L 63/1441*** (2013.01); *H04L 63/1491* (2013.01)

(58) **Field of Classification Search**
CPC H04L 63/168; H04L 63/1441; H04L 63/1491; G06F 21/54
See application file for complete search history.

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(Continued)

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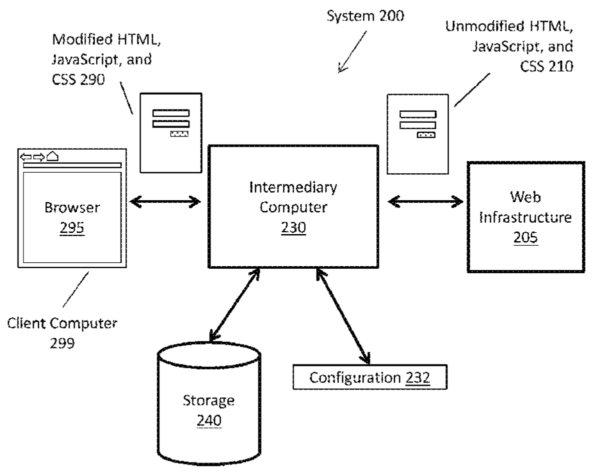
(74) *Attorney, Agent, or Firm* — Hickman Palermo Becker Bingham LLP

(57) ABSTRACT

In an embodiment, a data processing system comprises one or more processors; script analysis logic coupled to the one or more processors and configured to obtain a particular electronic document from a server computer; script injection logic coupled to the one or more processors and configured to insert a set of script code into source code of the electronic document to result in producing a modified electronic document prior to providing the modified electronic document to a client computer; wherein the script code is configured to improve resistance of the client computer to attacks by running upon loading in the client computer and to cause transforming, when running in the client computer, one or more values of one or more elements of the source code of the electronic document into obfuscated values of the one or more elements. As a result, the system and method herein improve resistance of the client computer to attacks.

20 Claims, 9 Drawing Sheets


System 200
Modified HTML, JavaScript, and CSS 290
Unmodified HTML, JavaScript, and CSS 210
Browser 295
Intermediary Computer 230
Web Infrastructure 205
Client Computer 299
Storage 240
Configuration 232

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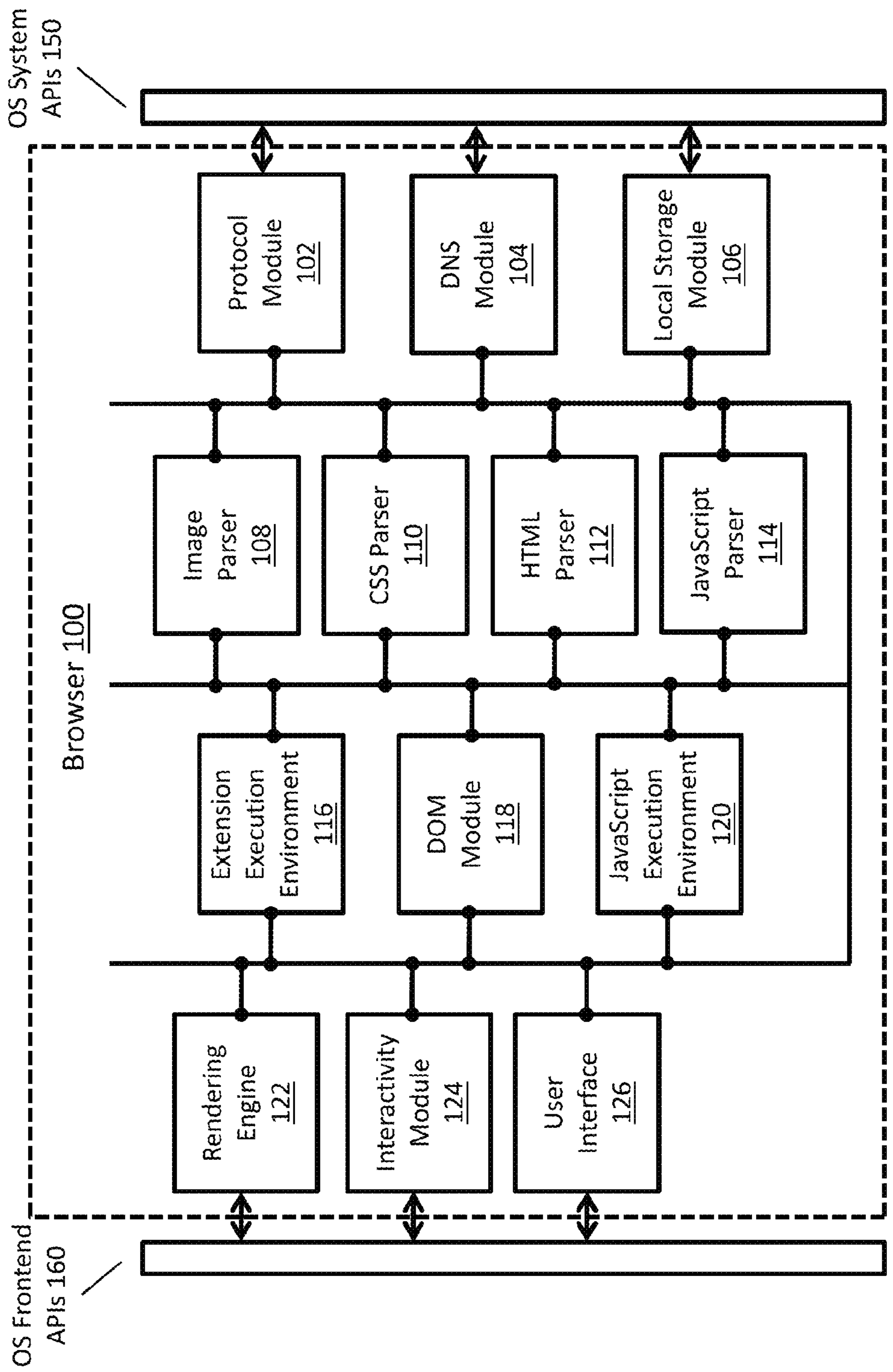
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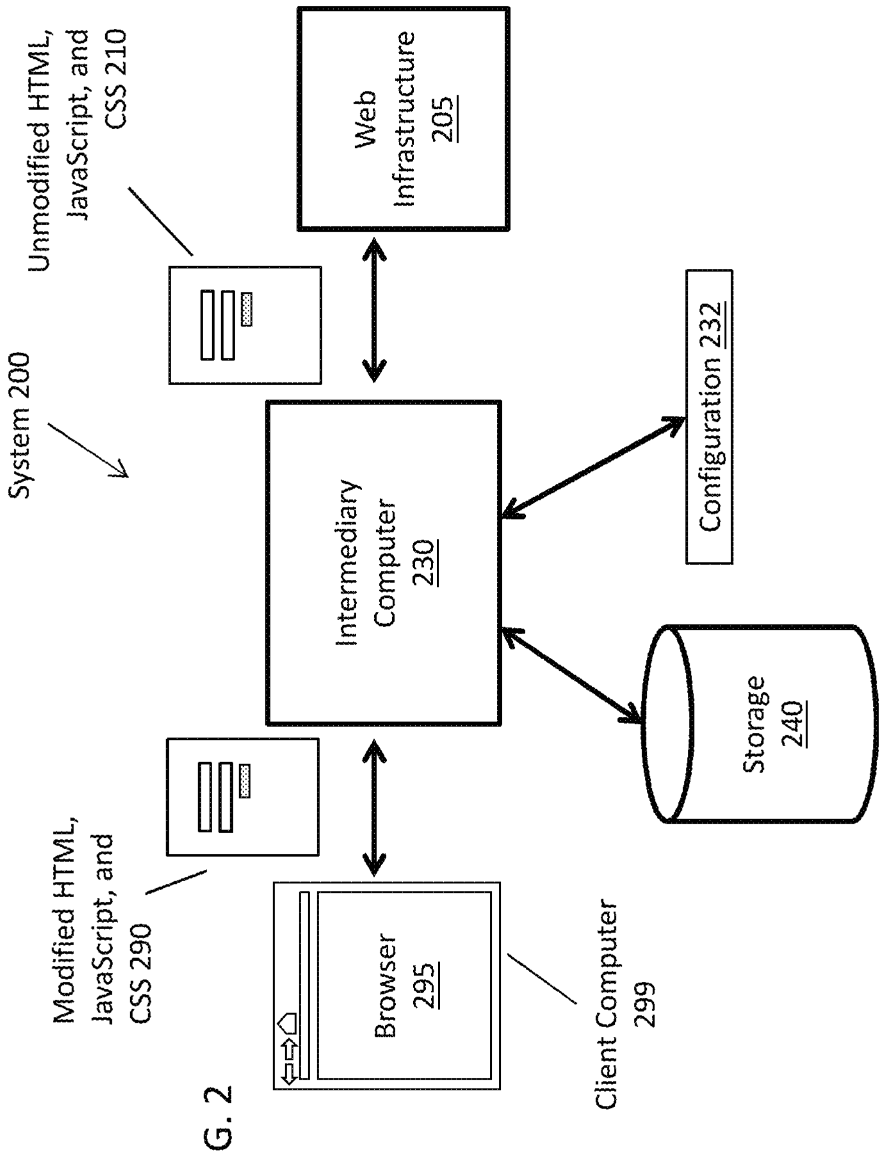
Browser 100
Protocol Module 102
DNS Module 104
Local Storage Module 106
Image Parser 108
CSS Parser 110
HTML Parser 112
JavaScript Parser 114
Extension Execution Environment 116
DOM Module 118
JavaScript Execution Environment 120
Rendering Engine 122
Interactivity Module 124
User Interface 126
OS Frontend APIs 160

FIG. 1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System 200
Intermediary Computer 230
Configuration 232
Storage 240
Modified HTML, JavaScript, and CSS 290
Browser 295
Client Computer 299

FIG. 2

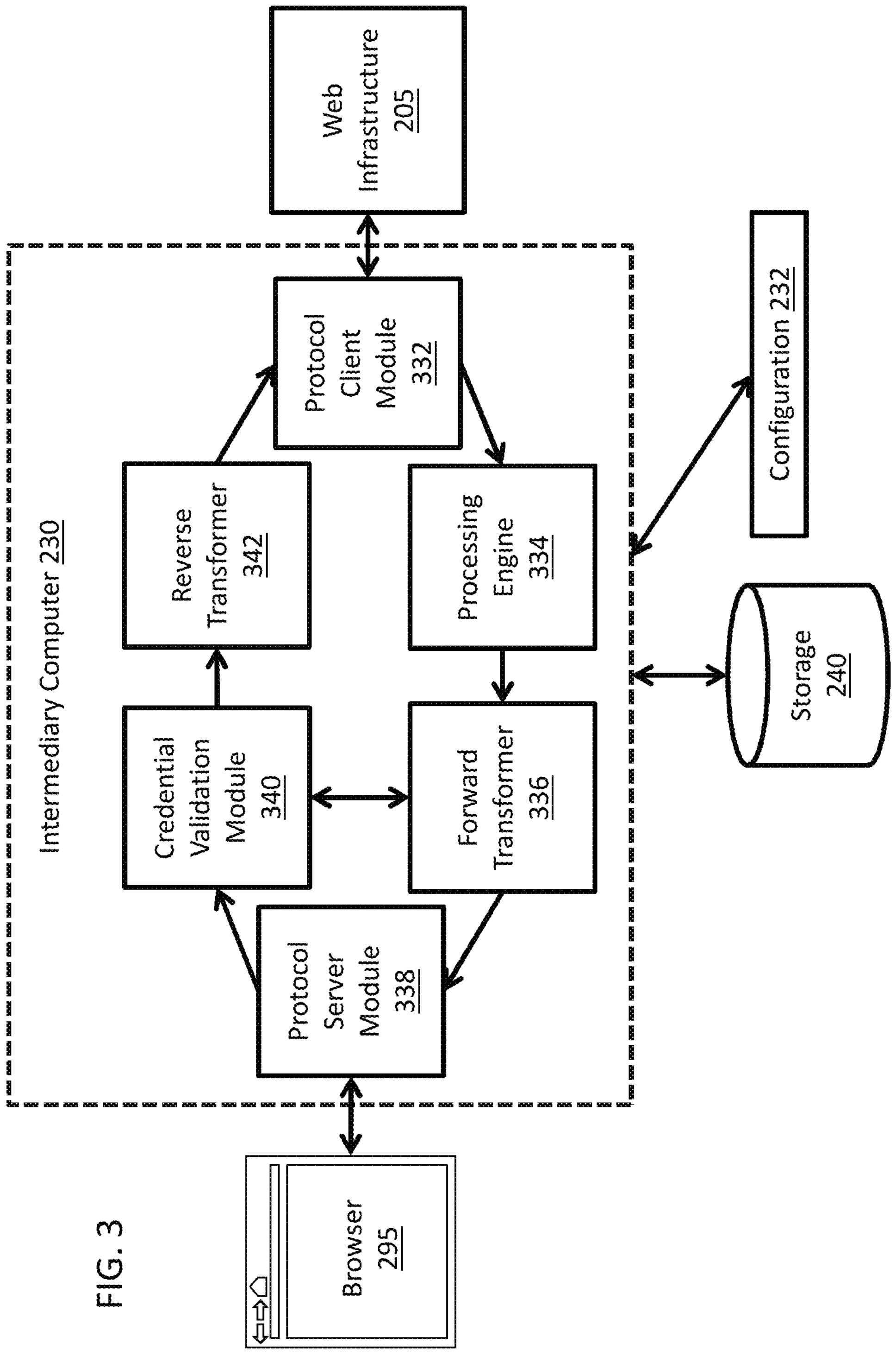

Web Infrastructure 205
Intermediary Computer 230
Protocol Client Module 332
Reverse Transformer 342
Processing Engine 334
Credential Validation Module 340
Forward Transformer 336
Protocol Server Module 338
Configuration 232
Storage 240
Browser 295

FIG. 3

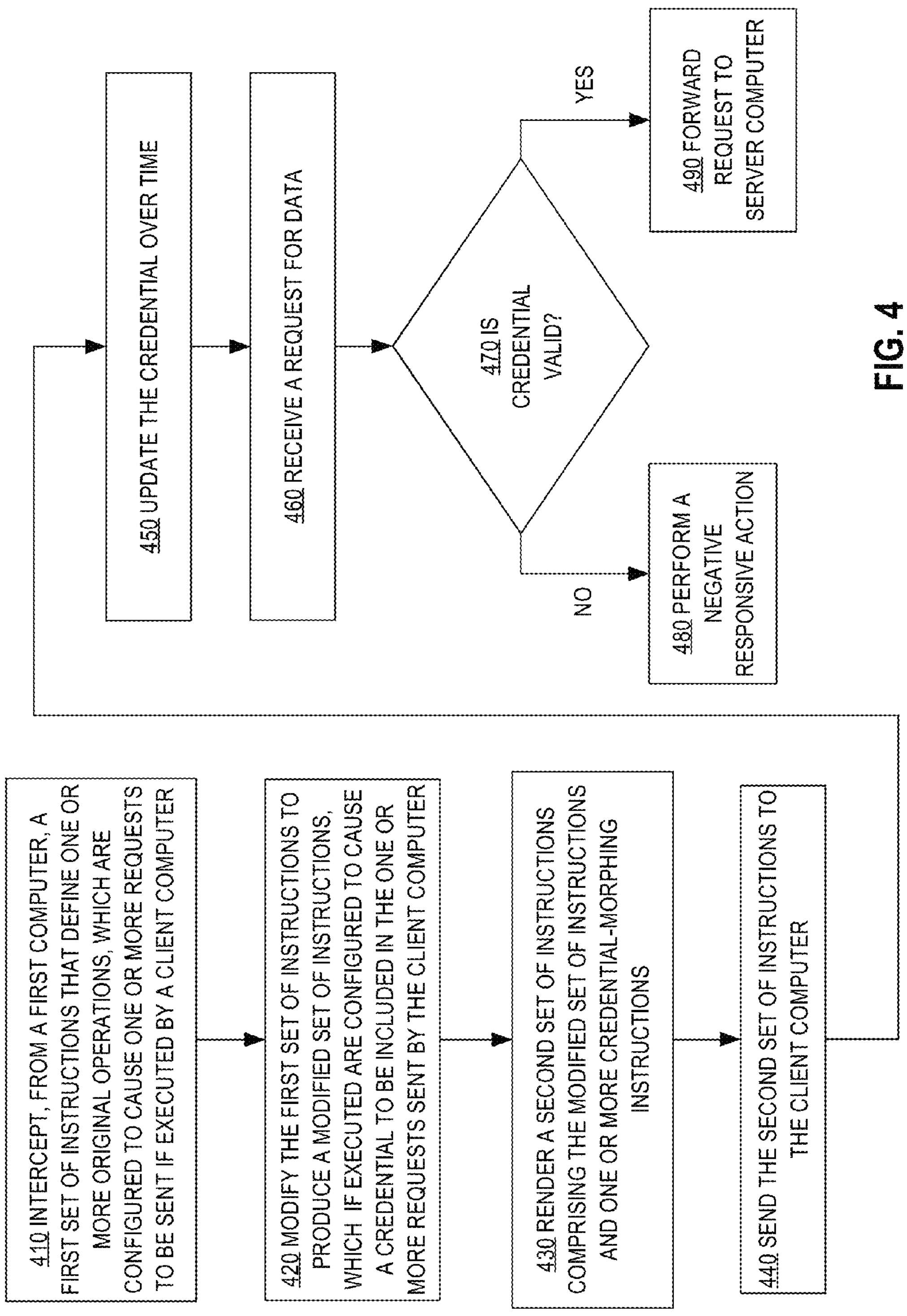

410 INTERCEPT, FROM A FIRST COMPUTER, A FIRST SET OF INSTRUCTIONS THAT DEFINE ONE OR MORE ORIGINAL OPERATIONS, WHICH ARE CONFIGURED TO CAUSE ONE OR MORE REQUESTS TO BE SENT IF EXECUTED BY A CLIENT COMPUTER
420 MODIFY THE FIRST SET OF INSTRUCTIONS TO PRODUCE A MODIFIED SET OF INSTRUCTIONS, WHICH IF EXECUTED ARE CONFIGURED TO CAUSE A CREDENTIAL TO BE INCLUDED IN THE ONE OR MORE REQUESTS SENT BY THE CLIENT COMPUTER
430 RENDER A SECOND SET OF INSTRUCTIONS COMPRISING THE MODIFIED SET OF INSTRUCTIONS AND ONE OR MORE CREDENTIAL-MORPHING INSTRUCTIONS
440 SEND THE SECOND SET OF INSTRUCTIONS TO THE CLIENT COMPUTER
450 UPDATE THE CREDENTIAL OVER TIME
460 RECEIVE A REQUEST FOR DATA
470 IS CREDENTIAL VALID?
NO
480 PERFORM A NEGATIVE RESPONSIVE ACTION
YES
490 FORWARD REQUEST TO SERVER COMPUTER

FIG. 4

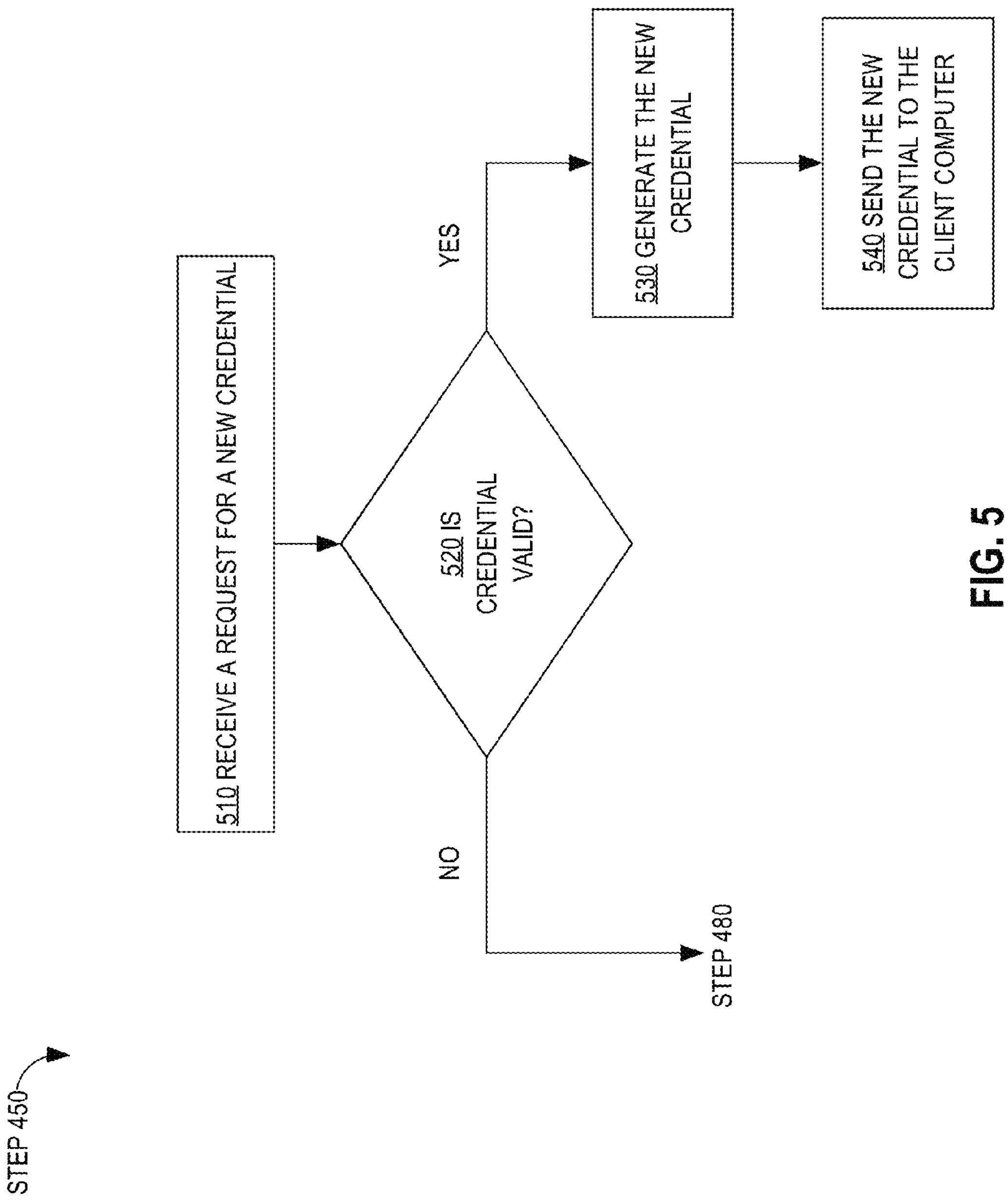

STEP 450
510 RECEIVE A REQUEST FOR A NEW CREDENTIAL
520 IS CREDENTIAL VALID?
YES
NO
STEP 480
530 GENERATE THE NEW CREDENTIAL
540 SEND THE NEW CREDENTIAL TO THE CLIENT COMPUTER

FIG. 5

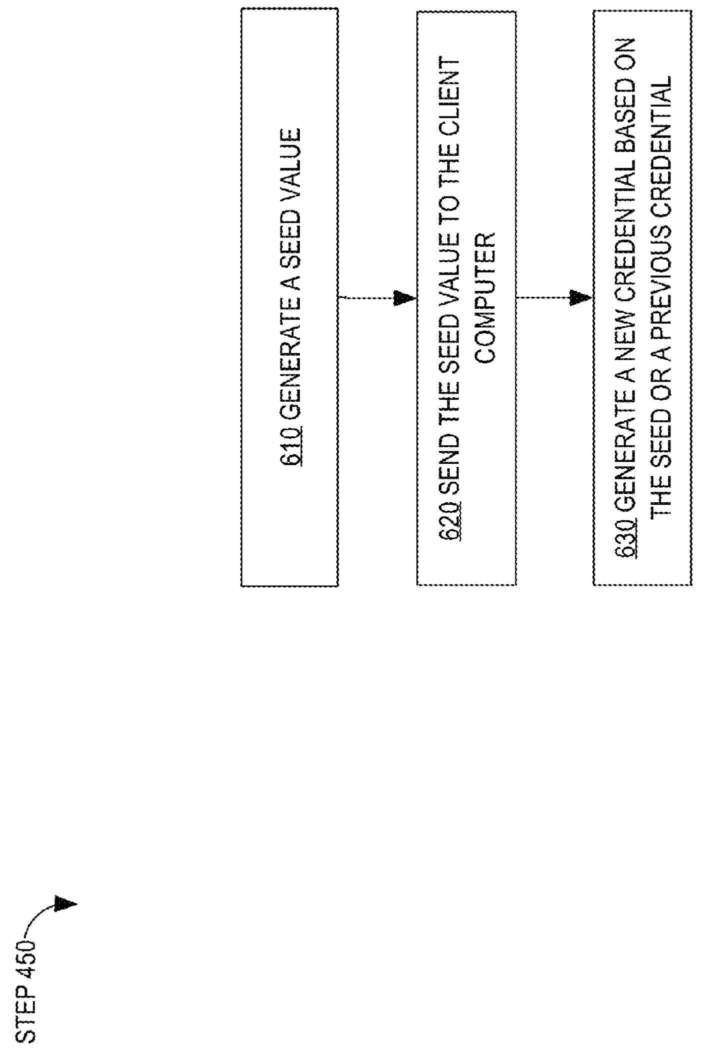

STEP 450
610 GENERATE A SEED VALUE
620 SEND THE SEED VALUE TO THE CLIENT COMPUTER
630 GENERATE A NEW CREDENTIAL BASED ON THE SEED OR A PREVIOUS CREDENTIAL

FIG. 6

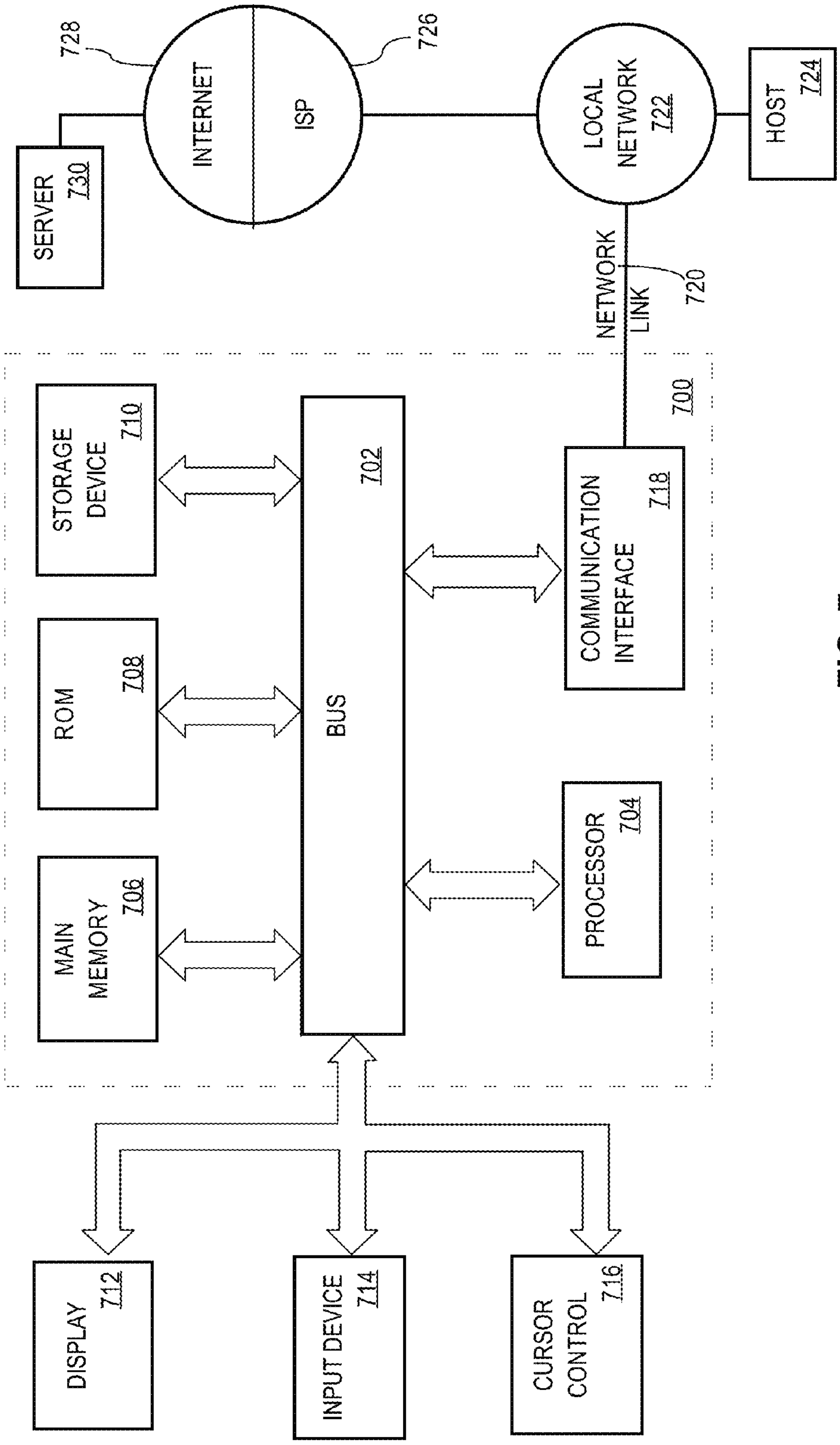

728
INTERNET
ISP
726
SERVER 730
LOCAL NETWORK 722
HOST 724
NETWORK LINK
720
700
STORAGE DEVICE 710
ROM 708
MAIN MEMORY 706
702
BUS
COMMUNICATION INTERFACE 718
PROCESSOR 704
DISPLAY 712
INPUT DEVICE 714
CURSOR CONTROL 716

FIG. 7

Fig. 8

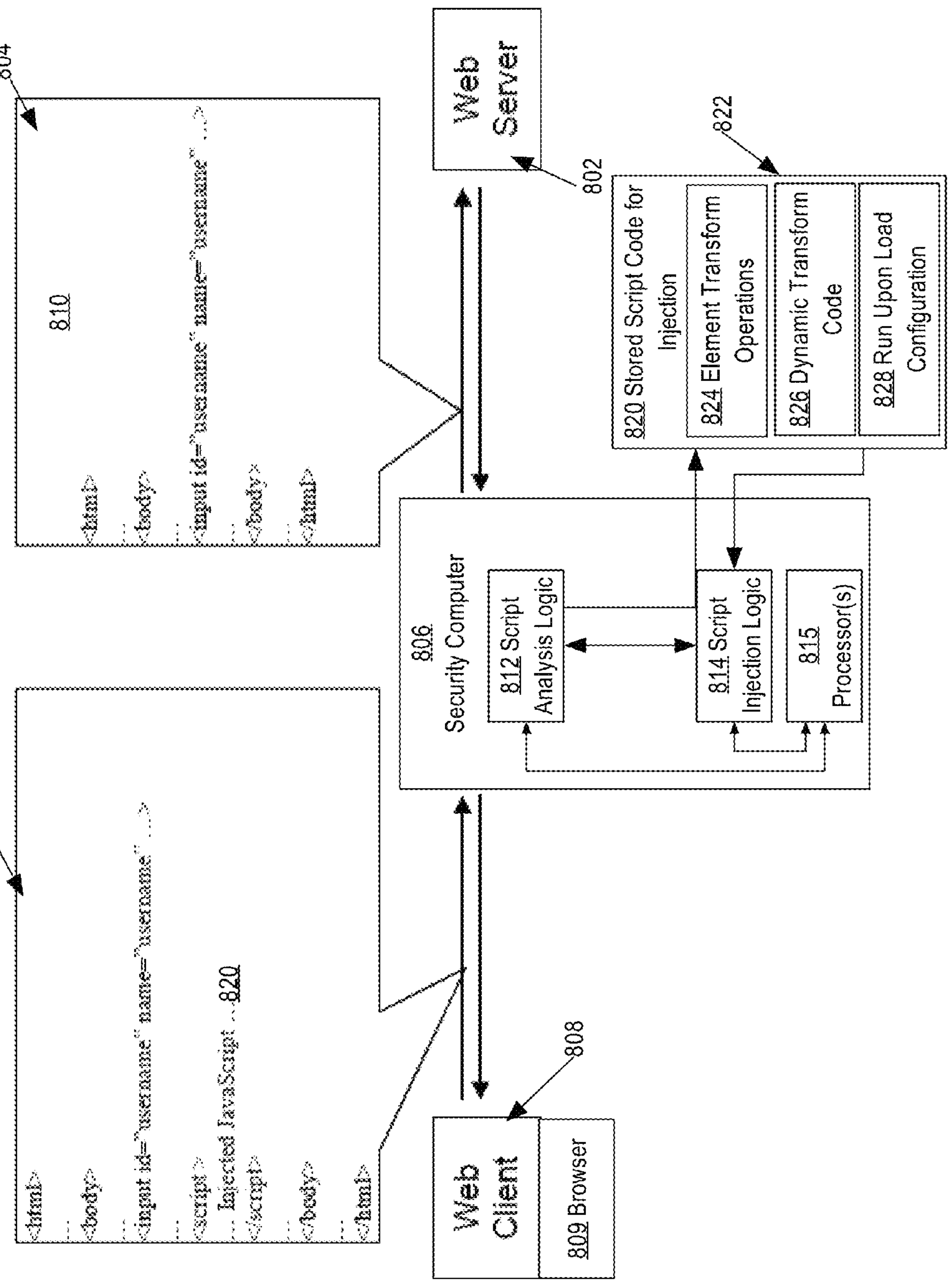
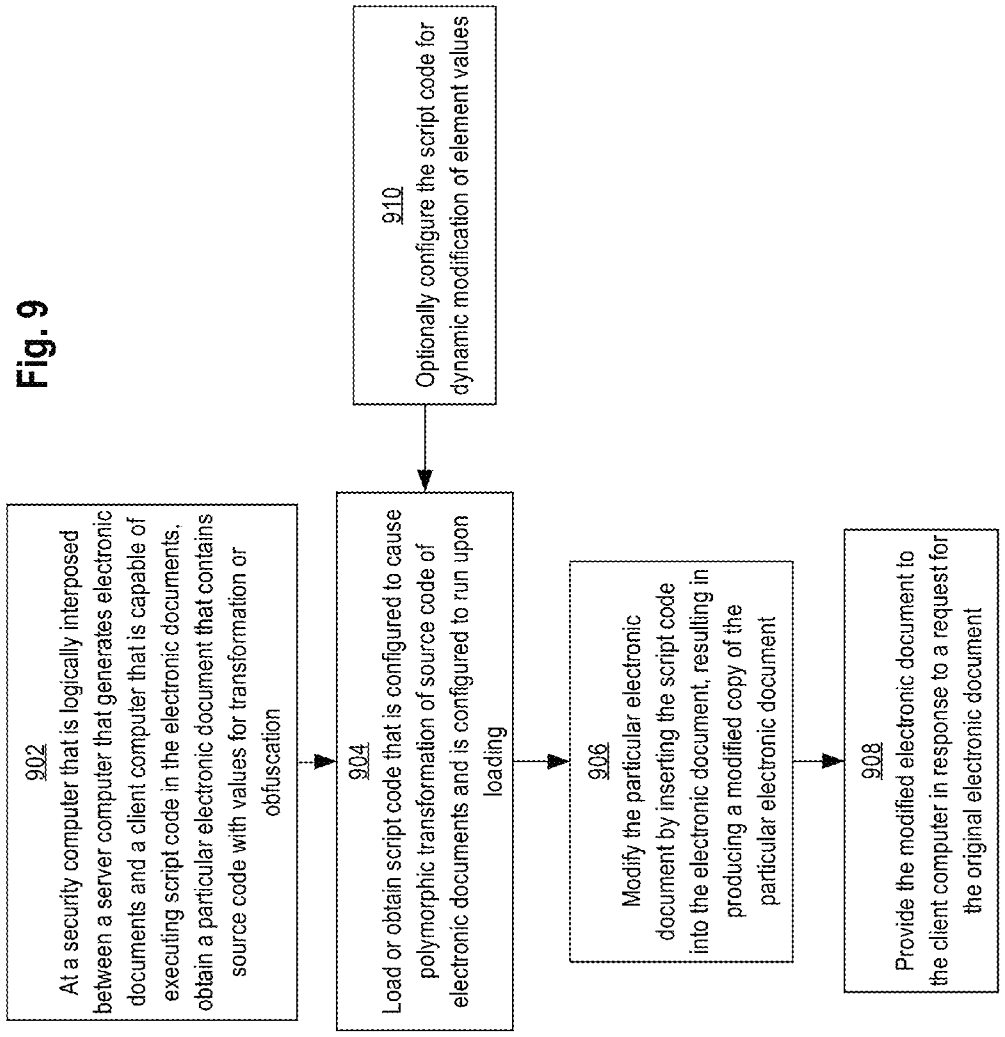

804
810
<html>
...
<body>
...
<input id="username" name="username" ...>
...
</body>
...
</html>
Web Server
802
822
820 Stored Script Code for Injection
824 Element Transform Operations
826 Dynamic Transform Code
828 Run Upon Load Configuration
806 Security Computer
812 Script Analysis Logic
814 Script Injection Logic
815 Processor(s)
814
<html>
...
<body>
...
<input id="username" name="username" ...>
...
<script>
Injected JavaScript ... 820
</script>
...
</body>
...
</html>
Web Client
809 Browser
808

Fig. 9


902
At a security computer that is logically interposed between a server computer that generates electronic documents and a client computer that is capable of executing script code in the electronic documents, obtain a particular electronic document that contains source code with values for transformation or obfuscation

904
Load or obtain script code that is configured to cause polymorphic transformation of source code of electronic documents and is configured to run upon loading

906
Modify the particular electronic document by inserting the script code into the electronic document, resulting in producing a modified copy of the particular electronic document

908
Provide the modified electronic document to the client computer in response to a request for the original electronic document

910
Optionally configure the script code for dynamic modification of element values

MITIGATING SCRIPTED ATTACKS USING DYNAMIC POLYMORPHISM

FIELD OF THE DISCLOSURE

The present disclosure generally relates to security techniques applicable to client/server systems, and relates more specifically to techniques for improving the resistance of client computers to attacks carried in browser-executed script code. SUGGESTED GROUP ART UNIT: 2447; SUGGESTED CLASSIFICATION: 709/217.

BACKGROUND

The approaches described in this section are approaches that could be pursued, but not necessarily approaches that have been previously conceived or pursued. Therefore, unless otherwise indicated, it should not be assumed that any of the approaches described in this section qualify as prior art merely by virtue of their inclusion in this section.

Browsers are powerful computer program applications that may request and execute instructions received from a web server to generate complex user interfaces that are presented to a user through one or more devices, such as a monitor or speakers. In response to input from a user, such as a mouse click indicating that the user selected a link, a browser may send a request based on the selected link to the web server. The request may be a request for data and/or include data to be processed by the web server.

A malicious user may use software, often referred to as a "bot", which imitates a browser by receiving instructions from a web server and generating requests based on those instructions. For example, a bot may receive a web page, and generate a request based on a link defined in the web page, as if the link was selected by a user. Also for example, a bot generate and send a request with data assigned to one or more parameters to simulate a user submitting data to a web server through a browser.

Malicious users may use bots to commit many types of unauthorized acts, crimes or computer fraud, such as content scraping, ratings manipulation, fake account creation, reserving rival goods attacks, ballot stuffing attacks, password snooping, web site scraping attacks, vulnerability assessments, and stack fingerprinting attacks. As a specific example, a malicious user may cause a bot to traverse through pages of a web site and collect private and/or proprietary data, such as who is connected with whom on a particular social networking web site.

Web server administrators may wish to prevent malicious users from attacking the site, while allowing legitimate users to use the site as intended. However, determining which requests are generated by a legitimate user using a web browser and a malicious user using a bot may be difficult.

Many presently implemented websites are vulnerable to attacks that are carried in browser-executed script code, such as Selenium, Sikuli and PhantomJS, in part because the HTML source code is readable by any browser user who invokes the VIEW SOURCE or INSPECT ELEMENT commands of the browser. Adversaries can write brief scripts which, when executed on an end user computer using the browser, can access static HTML elements such as form fields and embedded URLs to launch sophisticated attacks. These malicious scripts can generate protocol-compliant network traffic that appears legitimate to most existing security products, including firewalls, intrusion protection systems, and web application firewalls. Differentiating malicious scripts from legitimate human users is difficult.

One approach to computer security introduces static real-time polymorphism to web pages by transforming HTML form field attributes, such as field names and identifiers, to randomized string values. A "botwall" implementing this technique will change the form field name an ID for each client access to the same web page. This approach is effective to defeat malicious scripts that rely on static form field attributes. However, because the form field transformation does not change once the web content is delivered to the browser—that is, the polymorphism here is static—using a sufficient amount of reverse engineering effort, malicious users may be able to understand how the polymorphism was implemented and attempt to evade it.

SUMMARY

The appended claims may serve as a summary of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. **1** illustrates functional units of a web browser.

FIG. **2** illustrates a computer system comprising a browser, an intermediary computer, and a web infrastructure in an example embodiment.

FIG. **3** illustrates detailed view of an intermediary computer in an example embodiment.

FIG. **4** illustrates a process for validating requests from browsers, and filtering out requests from bots, using one or more dynamic credentials in an example embodiment.

FIG. **5** illustrates a process for updating a credential over time in an example embodiment.

FIG. **6** illustrates a process for generating a seed value and sending the seed value to the client computer to generate one or more new credentials in an example embodiment.

FIG. **7** illustrates a computer system upon which an embodiment may be implemented.

FIG. **8** illustrates a client-server computer system supporting dynamic polymorphism in script code, and with which an embodiment may be used.

FIG. **9** illustrates a computer-implemented process of using dynamic polymorphism to improve resistance to attacks embodied in script code.

While each of the drawing figures illustrates a particular embodiment for purposes of illustrating a clear example, other embodiments may omit, add to, reorder, and/or modify any of the elements shown in the drawing figures. For purposes of illustrating clear examples, one or more figures may be described with reference to one or more other figures, but using the particular arrangement illustrated in the one or more other figures is not required in other embodiments. For example, intermediary computer **230** in FIG. **2** may be described with reference to several components illustrated in FIG. **3** and discussed in detail below, but using the particular arrangement illustrated in FIG. **3** is not required in other embodiments. Furthermore, while the instructions discussed in many example embodiments are HTML, JavaScript, and CSS instructions, in other embodiments, the instructions intercepted and generated may be any other standard and/or proprietary instructions configured to be executed by a client computer.

DETAILED DESCRIPTION

In the following description, for the purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the present invention. It will be apparent, however, that the present invention may be practiced without these specific details. In other instances, well-known structures and devices are shown in block diagram form in order to avoid unnecessarily obscuring the present invention.

Embodiments are described herein according to the following outline:

1.0 General Overview

In an embodiment, a data processing system comprises one or more processors; script analysis logic coupled to the one or more processors and configured to obtain a particular electronic document from a server computer; script injection logic coupled to the one or more processors and configured to insert a set of script code into source code of the electronic document to result in producing a modified electronic document prior to providing the modified electronic document to a client computer; wherein the script code is configured to improve resistance of the client computer to attacks by running upon loading in the client computer and to cause transforming, when running in the client computer, one or more values of one or more elements of the source code of the electronic document into obfuscated values of the one or more elements.

The script code may be configured to cause the transforming using a pseudo-random transformation of the values of the elements. The script code may comprise two or more segments of a particular obfuscated value, and the script code may be configured to cause transforming a particular value of a particular element of the source code into a particular combination of the two or more segments. The script code may be configured to cause transforming the particular value of the particular element of the source code into a pseudo-randomly selected combination of the two or more segments. The script code may be configured to cause

transforming the particular value of the particular element of the source code into a randomly selected combination of the two or more segments.

The script code may be configured to repeatedly periodically execute in the client computer, and wherein the script code is configured to cause the transforming in a different manner at each time that the script code repeatedly periodically executes in the client computer. The script code may be configured to repeatedly periodically execute in the client computer at time intervals specified using a time interval value in the script code, and wherein the script injection logic is configured to periodically update the time interval value in the script code to a different time interval value.

In an embodiment, a data processing method comprises obtaining a particular electronic document from a server computer; inserting a set of script code into source code of the electronic document to result in producing a modified electronic document; providing the modified electronic document to a client computer; the script code may be configured to improve resistance of the client computer to attacks by running upon loading in the client computer and to cause transforming, when running in the client computer, one or more values of one or more elements of the source code of the electronic document into obfuscated values of the one or more elements.

2.0 Differences Between Browsers and Bots

A web browser may be a tool through which application programs can provide client computers with content in a dynamic, custom UI. For example, in response to receiving a request for data from a web browser, a web server responds with a set of instructions and/or data. The instructions may define one or more objects that include data and/or other objects. The instructions may also define how the data and/or objects may be presented in a UI to enable human/computer interaction.

In contrast, bots traverse web pages and/or web sites to retrieve data from, and/or submit data to, one or more web servers with little, if any, human/computer interaction. For example, in response to receiving a request for data from a bot, a web server responds with a set of instructions. As discussed above, the instructions may define one or more objects that include data and/or other objects. The instructions may also define how the data and/or objects may be presented in a UI. However, a bot may parse the instructions looking for particular data to store and/or use to make subsequent requests. A bot need not execute the instructions because the bot is built to operate with little, if any, human/computer interaction. The bot may simply look for data by parsing the one or more data structures defined in the instructions. Thus, a bot may be a functionally-limited browser.

A server computer that requires a browser to use one or more parsers and/or execution environments may filter out requests from bots. For purposes of illustrating a clear example, assume a browser includes a JavaScript parser or JavaScript execution engine, and a bot does not include a JavaScript parser or JavaScript execution engine. Also assume that a server computer may include one or more JavaScript instructions in a web page, which if executed, may cause a browser to request, receive, generate, and/or update a dynamic credential. A dynamic credential may be a credential that is updated over time. Accordingly, the browser may parse and execute the one or more JavaScript instructions, which cause the browser to request, receive, generate, and/or update the credential over time and include a valid dynamic credential in a subsequent request.

In contrast, a bot, which does not include a JavaScript parser and/or JavaScript execution environment, may not request, receive, generate, and/or update the dynamic credential over time. Thus, the bot may not include a valid dynamic credential in a subsequent request.

If a server computer receives a request for a web page with a valid dynamic credential from a browser, then the server computer may send the requested web page to the browser. However, if the server computer receives a request without a valid dynamic credential from the bot, then the server computer may perform a negative action, such as terminating the request or ignoring one or more future requests from the bot.

2.1 Example Browser Anatomy

FIG. **1** illustrates functional units of a web browser. Browser **100** may be a browser that is executed on a personal computer, used to communicate with or otherwise conceptually visit a web server, and operated by a user using the personal computer. Browser **100** is communicatively coupled with operating system ("OS") system application programming interface ("API") layer **150** and OS frontend API layer **160**. Other embodiments may use other protocols, modules, and/or parsers.

Browser **100** comprises protocol module **102**, domain name server ("DNS") module **104**, local storage module **106**, image parser **108**, CSS parser **110**, HTML parser **112**, JavaScript parser **114**, extension execution environment **116**, document object model ("DOM") module **118**, and JavaScript execution environment **120**. Protocol module **102**, DNS module **104**, and local storage module **106** may send and/or receive data through OS System API layer **150**. For example, protocol module **102** may send and/or receive data over any protocol, such as HTTP, to/from a server computer through OS system API layer **150**. Data received through protocol module **102** may reference data sources by one or more domain names. DNS module **104** may resolve the one or more domain names referenced by interfacing with one or more remote domain name servers through OS system API layer **150**. Local storage module may store and/or recall data from memory through OS system API layer **150**.

Image parser **108**, CSS Parser **110**, HTML parser **112**, and JavaScript parser **114** may parse data received through protocol module **102**. HTML parser **112** may parse HTML data. CSS parser **110** may parse CSS data. JavaScript parser **114** may parse JavaScript data. Image parser **108** may parse image data. Each parser may generate and/or update objects in a DOM maintained by DOM module **118**.

Browser **100** may comprise sets of program logic implementing one or more programmable engines, such as extension execution environment **116** and JavaScript execution environment **120**. Extensions may be written one or more programming languages include JavaScript, Python, Ruby, and/or any other language. Each programmable engine may have access to DOM module **118** and may operate on one or more objects from a DOM maintained by DOM module **118**. For example, JavaScript execution environment **120** may execute JavaScript parsed by JavaScript parser **114** and in response, create, update, and/or delete one or more objects managed by DOM module **118**, and/or one or more aspects of a UI presenting the one or more objects.

Browser **100** comprises rendering engine **122**, interactivity module **124**, and user interface **126**. Each of the components may cause, through OS frontend API layer **160**, one or more objects to be presented to a user using a client computer. Rendering engine **122** may determine how objects are presented to a user. For example, rendering engine **122** may determine the color, shape, orientation, position, and/or any other visual and/or audio attribute of an image, text field, button, and/or any other object defined by a set of received instructions. Furthermore, rendering engine **122** may cause a button to be displayed on a monitor coupled to a client computer through OS frontend API layer **160**.

User interface **126** may determine what may be presented to a user. For example, user interface **126** may determine that a "submit" button should be hidden until data has been entered in one or more text fields. After data has been entered in the one or more text fields, user interface **126** may notify rendering engine **122** to render the "submit" button accordingly.

Interactivity module **124** may receive one or more inputs through OS Frontend API layer **160**. For example, in response to a user pressing a button on a mouse coupled to a client computer **299**, the OS running on the client computer may send a message to interactivity module **124**, through OS frontend API layer **160**, to indicate that a user pressed a button on a mouse. Interactivity module **124** may determine that a user selected a particular button currently presented on a monitor. Interactively module **124** may notify user interface **126** and/or rendering engine **122** to update to update the UI accordingly.

2.2 Example Bot Anatomy

A bot may include a subset of the modules and/or features included in browser **100**. For example, a bot may include protocol module **102**, DNS module **104**, local storage module **106**, and HTML parser **112**. A bot need not support a UI; thus, a bot need not include rendering engine **122**, interactivity module **124**, and user interface **126**.

To increase processing time and speed of development, a bot need not include one or more parsers and/or execution environments. For example, a bot may be configured to look for data embedded in a DOM defined in one or more HTML documents. Therefore, a bot may include an HTML parser. However, a bot need not include one or more parsers or execution environments, such as image parser **108**, CSS parser **110**, JavaScript parser **114**, extension execution environment **116**, and/or JavaScript execution environment **120**.

3.0 Network Topology

FIG. **2** illustrates a computer system comprising a browser, an intermediary computer, and a web infrastructure in an example embodiment. Referring first to FIG. **2**, system **200** includes web infrastructure **205**, client computer **299**, intermediary computer **230**, storage **240**, and configuration **232** distributed across a plurality of interconnected networks.

While each of the components listed above is illustrated as if running on a separate, remote computer from each other, one or more of the components listed above may be part of and/or executed on the same computer. For example, intermediary computer **230**, configuration **232**, storage **240**, and/or web infrastructure **205** may be executed on the same computer, local area, and/or wide area network. Additionally or alternatively, intermediary computer **230** may be a proxy server and/or layer for web infrastructure **205**. Additionally or alternatively, intermediary computer **230** may be in line between a router and web infrastructure **205**, such that intermediary computer **230** may intercept all network data sent to, and/or sent from, web infrastructure **205** over one or more protocols. Additionally or alternatively, intermediary computer **230**, and/or one or more modules comprising intermediary computer **230** discussed herein, may be a software layer between, and/or executed on, web infrastructure **205** and/or a component of web infrastructure **205**. Additionally or alternatively, intermediary computer **230**, and/or one or more modules comprising intermediary computer **230** discussed herein, may be part of a server-side application that responds to requests over one or more standard and/or proprietary protocols, such as HTTP and/or any other protocol.

3.1 Web Infrastructure

Web infrastructure **205** may comprise one or more server computers that receive requests for data from users through one or more computers, such as client computer **299** and/or intermediary computer **230**. Web infrastructure **205** may respond by sending data to the browser that sent the request. As illustrated in FIG. **2**, the data sent from web infrastructure **205** may include instructions: HTML, JavaScript, and CSS **210**. The one or more computers in web infrastructure **205** may, but need not, be owned and/or managed by one or more independent entities and may span across one or more computer networks.

A server computer may be a computer that receives requests for data and responds with data. For example, a web server computer may be an HTTP-based computer that receives HTTP requests and responds with data comprising HTML, CSS, and/or JavaScript instructions. Additionally or alternatively, a server computer may respond with data that references data on other server computers in, and/or outside of, web infrastructure **205**.

3.2 Intermediary Computer

Intermediary computer **230** may be an intermediary that may intercept instructions sent from web infrastructure **205**, parse and/or execute one or more of the intercepted instructions, modify the intercepted instructions, generate and/or add new instructions, and send the modified and/or new instructions to a client computer. For example, intermediary computer **230** may intercept HTML, JavaScript, and CSS **210**, generate modified HTML, JavaScript, and CSS **290**, and send modified HTML, JavaScript, and CSS **290** to browser **295**. Intermediary computer **230** may intercept a request from browser **295**, generate a new and/or modified request, and send the new and/or modified request to web infrastructure **205**.

Intermediary computer **230** may be an HTTP or SPDY intermediary that intercepts, parses, executes, and/or processes HTML, JavaScript, and CSS instructions. Additionally or alternatively, intermediary computer **230** may intercept requests for data and/or instructions from a client application, generate a new HTTP request, and send the newly generated HTTP request to one or more HTTP and/or SPDY-based web servers. Additionally or alternatively, intermediary computer **230** may be an intermediary for any other standard and/or proprietary protocol. Furthermore, each of the components discussed herein, which intermediary computer **230** is comprised of, may be configured to perform any of the processes and/or methods discussed herein for any standard and/or proprietary protocol.

Intermediary computer **230** may be a server computer that one or more domain name servers or other elements of the domain name system ("DNS") identify in DNS records as a destination network address associated with one or more internet domain names. Accordingly, intermediary computer **230** and/or intermediary computer **230** may receive requests sent to the one or more domains from a browser or bot. Based on using DNS to resolve the domain name in a request to a network address, intermediary computer **230** may forward the request, or a modified request, to a server computer in web infrastructure **205**, such as original web server computer **302**.

In FIG. **2**, intermediary computer **230** is programmed to send instructions to, and receive requests from, a particular type of client application: browser **295**. However, in an embodiment, intermediary computer **230** may be programmed to send instructions to, receive requests from, and/or open sockets with browsers and/or bots.

FIG. **3** illustrates detailed view of an intermediary computer in an example embodiment. In FIG. **3**, intermediary computer **230** comprises protocol client module **332**, processing engine **334**, forward transformer **336**, protocol server module **338**, credential validation module **340**, and reverse transformer **342**. In an embodiment, each of the functional units of intermediary computer **230** may be implemented using any of the techniques further described herein in connection with FIG. **7**; for example, the intermediary computer **230** may comprise a general-purpose computer configured with one or more stored programs which when executed cause performing the functions described herein for the intermediary computer, or a special-purpose computer with digital logic that is configured to execute the functions, or digital logic that is used in other computing devices. While the figures include lines that indicate various devices and/or modules being communicatively coupled, each of the computers, devices, modules, storage, and configurations may be communicatively coupled with each other.

3.2.1 Protocol Client Module

Protocol client module **332** may intercept data over any standard or proprietary protocol. For example, protocol client module **332** may intercept data over HTTP.

3.2.2 Processing Engine

Processing engine **334** may process instructions intercepted by protocol client module **332**, which causes processing engine **334** to generate one or more data structures. Processing one or more instructions may comprise parsing and/or executing the one or more instructions. After processing the instructions, processing engine **334** may notify forward transformer **336** to begin rendering instructions based on the one or more data structures created by processing engine **334** that are currently in memory.

Processing engine **334** may make requests for additional data. For example, if instructions received from protocol client module **332** reference additional instructions stored on another web server, then processing engine **334** may request the additional instructions through protocol client module **332**.

3.2.3 Forward Transformer

Forward transformer **336** may render a new set of instructions based on the one or more data structures in memory. Additionally or alternatively, forward transformer **336** may operate on the objects created by processing engine **334** and generate one or more credential-morphing-instructions, which if executed are configured to cause a browser to request, receive, generate, and/or update one or more dynamic credentials. Forward transformer **336** may store the one or more dynamic credentials and/or data associated with one or more dynamic credentials in storage **240**. Forward transformer **336** may operate on objects and/or render instructions based on one or more configurations specified in configuration **232**. Forward transformer **336** may send the rendered instructions to one or more client computers through protocol server module **338**.

3.2.4 Protocol Server Module

Protocol server module **338** may receive the instructions generated by forward transformer **336** and send the generated instructions to client computer **299**. Additionally or alternatively, protocol server module **338** may intercept requests from client computer **299** and forward the requests to credential validation module **340**.

3.2.5 Credential Validation Module

Credential validation module **340** may receive requests intercepted by protocol server module **338** from browser **295**. Credential validation module **340** may validate requests and/or credentials, and forward the requests for one or more pages to reverse transformer **342**.

Credential validation module **340** may generate one or more dynamic credentials. For example, forward transformer **336** may render a page and embed a dynamic credential received from credential validation module **340** into the page. Also for example, in response to a request from a client computer for a dynamic credential, credential validation module **340** may generate a new, valid dynamic credential and send the new dynamic credential to the client computer through protocol server module **338**.

Credential validation module **340** may generate one or more parameters associated with dynamic credential. For example, credential validation module **340** may store a credential, a timestamp, and an Internet Protocol ("IP") address in storage **240**. As discussed in detail herein, credential validation module **340** may validate a request with the stored credential based on the timestamp and the IP address associated with the stored credential.

Credential validation module **340** may authorize requests based on configuration **232**. For purposes of illustrating a clear example, assume that configuration **232** includes data indicating that a particular web page is public. In response to a request for the particular web page, which does not include a dynamic credential, credential validation module **340** may authorize the request based on configuration **232**.

3.2.6 Reverse Transformer

Reverse transformer **342** may translate requests intercepted by protocol server module **338**, which are based on instructions generated by forward transformer **336**, into requests that would have been generated by browser **295** had browser **295** received the original instructions sent from web infrastructure **205**. For example, if a request from browser **295** includes a dynamic credential generated by credential validation module **340**, then reverse transformer **342** may generate a new request that does not include the dynamic credential. Reverse transformer **342** may send the new request web infrastructure **205** through protocol client module **332** on behalf of browser **295**.

3.2.7 Configurations

Configuration **242** may be a database, a configuration file, and/or any other system that stores configurations: settings, preferences, and/or protocols. Configuration **242** may store more than one configuration for one or more web servers in web infrastructure **205**. For example, configuration **232** may include data that indicates requests to a particular server computer in web infrastructure **205** need not be validated. Additionally or alternatively, configuration **232** may include data that indicates requests for a particular web page need not be validated. Additionally or alternatively, configuration **232** may include data that indicates requests to submit data to a particular web site need not be validated. Also for example, configuration **232** may include data that indicates whether particular web pages should be processed by processing engine **334** and/or modified by forward transformer **336**.

Configuration **232** may be modified by a user and/or administrator through one or more computers, such intermediary computer **230**, a computer in web infrastructure **205**, and/or any other computer. The one or more computers may present the user with an interface that presents the user with a site map. The site map may comprise a graph, wherein the nodes correspond to pages and the edges between the nodes correspond to links.

The user may update configuration **232**, through the interface, by selecting which links and/or pages to be "public" (do not require a valid credential) and which links and/or pages are "private" (require a valid credential). For example, the interface may receive input from a user indicating that a page is public. Configuration **232** may be updated accordingly. When a request is received for the particular page, even if the request does not have a valid credential, intermediary computer **230** may pass the request to web infrastructure **205**. Also for example, the interface may receive input from a user indicating that a link, with a particular link identifier, is public. When intermediary computer **230** receives a request that includes a particular link identifier, then intermediary computer **230** may pass the request to web infrastructure **205** even if the request does not have a valid credential.

3.2.8 Storage

Storage **240** may be a database, a configuration file, and/or any other system and/or data structure that stores data. In FIG. **2**, storage **240** is illustrated as if a separate computer from intermediary computer **230**. Additionally or alternatively, storage **240** may be a data structure stored in memory on the one or more computers comprising intermediary computer **230**. Additionally or alternatively, storage **240** may, at least in part, be a data structure stored in shared memory between one or more intermediary computers. Additionally or alternatively, intermediary computer **230** may, at least in part, be stored in volatile and/or non-volatile memory.

3.3 Browser

Browser **295** may be a browser as described herein and executed on a client computer, such as client computer **299**. Additionally or alternatively, browser **295** may be a bot comprising one or more of the components traditionally found in a browser.

4.0 Process Overview

In an embodiment, a data processing method may be configured to intercept instructions from a server computer that are directed toward a browser, modify the intercepted instructions, include one or more credential-morphing-instructions, render a second set of instructions comprising the modified set of instructions and one or more credential-morphing-instructions. In an embodiment, a data processing method may be configured to receive requests from a browser for a new credential from a client application, validate the request using a previous credential, generate the new credential, and send the new credential to the browser. In an embodiment, a data processing method may be configured to receive requests from a client computer for data on a server computer, validate the request based on a dynamic credential. In an embodiment, if the request is valid, then the processing method may be configured to modify the request, send the modified request to a server computer, receive data from the server computer in response to the modified request, and/or send a response to a client computer. Various embodiments may use standard web protocols, such as HTTP, and/or standard web-based instructions, such as HTML, CSS, and/or JavaScript. Additionally or alternatively, other standard and/or proprietary protocols may be used. Additionally or alternatively, other standard and/or proprietary instructions may be used.

4.1 Intercepting Instructions from a Content Server Computer

FIG. **4** illustrates a process for validating requests from browsers, and filtering out requests from bots, using one or more dynamic credentials in an example embodiment. In step **610**, an intermediary computer intercepts, from a first computer, a first set of instructions that define one or more original operations, which are configured to cause one or more requests to be sent if executed by a client computer. For example, protocol client module **332** may receive instructions from web infrastructure **205**. The instructions may comprise HTML, CSS, and/or JavaScript. The HTML, may define one or more links, forms, and/or Uniform Resource Locators ("URLs") that a request may be sent to send and/or receive data.

4.2 Modifying Instructions which Cause a Browser to Submit a Credential with One or More Requests

In step **420**, the intermediary computer modifies the first set of instructions to produce a modified set of instructions, which if executed are configured to cause a credential to be included in the one or more requests sent by the client computer. For purposes of illustrating a clear example, assume that the instructions received in the previous step comprise HTML, CSS, and JavaScript instructions that define a link, which a browser or bot may use to generate a request for additional data and/or instructions. Processing engine **334** may parse the instructions. Forward transformer **336** may identify the link processed by processing engine **334**. Forward transformer **336** may modify the instructions that define the link, such that if the link is selected by a user using a browser, then the browser executes a JavaScript callback that causes the browser to modify the URL, one or more parameters in the URL, and/or data submitted in a request based on the URL, to include a dynamic credential. Accordingly, when the browser generates the request based, at least in part on the URL, the request includes a dynamic credential. The foregoing is an example of a technique for modifying instructions to cause a browser to include a credential in a URL. Other embodiments may use one or more other techniques.

For purposes of illustrating another clear example, assume that the instructions received in the previous step define a form that is associated with a submit method. The submit method may be configured to collect data from one or more of the fields in the form and send the collected data in a request, such as an HTTP POST request, to a server computer. After processing engine **334** parses the instructions, forward transformer **336** may add a new field in the form that includes a dynamic credential. Accordingly, when the submit method is executed, the browser may generate a request that includes the credential stored in the added field with other data from other fields in the form. Additionally or alternatively, forward transformer may generate a wrapper for the previously defined submit method. The wrapper may be configured to call the previously defined submit method and tack on a credential in the payload of the request.

Additionally or alternatively, intermediary computer **230** may determine whether to parse and/or modify instructions based on configuration **232**. For example, if protocol client module **332** receives a set of original instructions in response to a request for a particular web page, and configuration **232** includes data that indicates the particular web page is a public page and/or should not be modified, then processing engine **334** and/or forward transformer **336** may send the original instructions to the intended client computer without processing or modifying the instructions. Also for example, if processing engine **334** and/or forward transformer **336** determine that a set of instructions define a particular link to a particular target page and/or URL, and if configuration **232** includes data that indicates the particular link and/or the particular target page and/or URL are protected, then forward transformer **336** may modify the instructions that define the particular link. Similarly, if processing engine **334** and/or forward transformer **336** determine that a set of instructions define a particular link to a particular target page and/or URL, and if configuration **232** includes data that indicates the particular link and/or the particular target page and/or URL are public, then forward transformer **336** may modify the instructions that define the particular link.

In the above examples, the modified instructions may be executed by a browser using one or more particular parsers and/or execution environments, such as JavaScript parser **114**, extension execution environment **116**, and/or JavaScript execution environment **120**. Thus, a bot without the particular parser(s) and/or execution environment(s) needed to parse and execute the modified instructions may not generate a request that includes a dynamic credential. Accordingly, a request for instructions and/or data from a bot may be dismissed, ignored, and/or other responded to in a negative manner.

The modified instructions need not include a valid credential. The modified instructions may merely cause a credential to be included in one or more requests sent by the client computer. How a valid dynamic credential is requested, received, and/or generated is discussed in detail herein.

4.3 Rendering a Second Set of Instructions Comprising Credential-Morphing-Instructions

In step **430**, the intermediary computer renders a second set of instructions comprising the modified set of instructions and one or more credential-morphing-instructions. The one or more credential-morphing-instructions may define one or more operations causing a browser with a particular parser and/or execution environment to request, receive, generate, and/or update a valid credential that changes over time. For example, forward transformer **336** may render a second set of instructions that include the modified instructions and credential morphing-instructions comprising one or more JavaScript instructions, which if parsed and/or executed are configured to cause a browser to request, receive, generate, and/or update a valid credential that changes over time. Additionally or alternatively, forward transformer **336** may include the credential-morphing-instructions by including a reference to a file with credential-morphing-instructions, such as an additional JavaScript file, in the rendered instructions.

If a bot does not have the particular parser and/or execution environment necessary to execute the credential-morphing-instructions, then the bot may not have a valid dynamic credential to submit with a subsequent request. Accordingly, subsequent requests from bots may be dismissed, ignored, and/or otherwise negatively dealt with as discussed herein. However, requests from browsers may be processed as if uninterrupted by an intermediary.

4.4 Sending the Modified and Credential-Morphing-Instructions to the Client Computer

In step **440**, the intermediary computer sends the second set of instructions, which comprise the modified instructions and the credential morphing-instructions to the client computer. For example, forward transformer **336** may send the modified instructions in step **420** and the credential-morphing-instructions in step **430** to browser **295**.

4.5 Updating the Credential Over Time

In step **450**, the client computer parses and/or executes the credential-morphing-instructions and updates the credential over time. The credential-morphing-instructions may cause the client computer, and/or browser executing on the client computer, to perform one or more methods to update a credential over time. In an embodiment, the credential may be stored in storage on a client computer, intermediary computer, and/or storage. The storage may, but need not be, non-volatile storage. When a new credential is received and/or generated, the old credential is deleted. Each newly received and/or generated credential may replace a previous credential at the particular address in memory that the previous credential was stored.

FIG. **5** illustrates a process for updating a credential over time in an example embodiment. In step **510**, the intermediary computer receives a request for a new credential. For purposes of illustrating a clear example, assume that browser **295** receives the second set of instructions sent in step **440**, and that the credential-morphing-instructions, if executed, are configured to cause browser **295** to request a new credential from intermediary computer **230**. Accordingly, browser **295** may parse and/or execute the credential-morphing-instructions using JavaScript parser **114** and JavaScript execution environment **120** to send a request for a new credential to intermediary computer **230**. If browser **295** has already received and/or generated a credential, then browser **295** may send one or more of the previously received and/or generated credential in the request. Protocol server module **338** may receive the request and forward the request to credential validation module **340**.

4.6 Validating a Credential

In step **520**, the intermediary computer determines whether the credential is valid. For example, credential validation module **340** may determine that the old credential is valid if it is stored in storage **240** and/or other storage device. Additionally or alternatively, credential validation module **340** may determine that a credential is valid based on one or more implied and/or express parameters. If credential validation module **340** determines that each of the parameters is satisfied, then control may pass to step **530**. Otherwise, control may pass to step **480**.

Credential validation module **340** may delete a credential and/or one or more parameters associated with the credential after credential validation module **340** validates the credential. Thus, credential validation module **340** need not validate the same credential more than once.

Bots may request additional web pages quickly compared to a user viewing a page and selecting a link. To thwart and slow down one or more requests from bots, a credential may have a parameter that indicates the credential is invalid for a first amount of time before it becomes valid for a second period of time. Thus, if a bot is able to determine a valid credential and quickly sends a request with the credential to the intermediary computer, the intermediary computer may determine that the credential is invalid and pass to step **480**.

A credential may be associated and/or embedded with one or more implied and/or express parameters. For example, a credential may be, and/or be associated with, a timestamp, a time range, an IP address, a subnet, a browser identifier, a username, a password, a keyword, a randomly generated value, and/or any other identifier and/or key that may be used to determine whether a credential is valid.

4.6.1 Implied Parameters

An implied parameter may be a parameter that is inherent to the credential. For example, a credential may be based on time, and credential validation module **340** may determine the time from the credential. Credential validation module **340** may be configured to determine that a credential is valid if the determined time is within a particular amount of time from the current time. Similarly, credential validation module **340** may be configured to determine that a credential is invalid if the determined timestamp identifies a time that is outside a particular amount of time from the current time.

4.6.2 Express Parameters

An express parameter may be a parameter that is associated with, and/or embedded in, a credential. For example, a credential may be associated with a parameter stored in storage **240**, which indicates the time at which the credential is no longer valid. Credential validation module **340** may query for the parameter stored in storage **240** based on the credential. If the current time is less than the time retrieved from storage **240**, then credential validation module **340** may determine that the old credential is valid. Otherwise, credential validation module **340** may determine that the credential is invalid.

Additionally or alternatively, a credential may include one or more encrypted parameters. Instead of storing one or more parameters in storage **240**, credential validation module **340** may generate a credential that comprises one or more encrypted parameters. Credential validation module **340** may validate the credential by decrypting the one or more encrypted parameters and determining whether each of the decrypted parameters is satisfied. If so, then credential validation module **340** may determine the credential is valid. Otherwise, credential validation module **340** may determine the credential is invalid.

4.7 Generating a New Credential

In step **530**, the intermediary computer generates a new credential. For example, credential validation module **340** may generate a new credential with one or more implied and/or express parameters. The one or more parameters may include any of the parameters discussed above, and/or any other value, identifier, and/or key that may be used to determine whether the new credential is valid. Credential validation module **340** may store the new credential and/or the one or more parameters in storage **240**. Additionally or alternatively, credential validation module **340** may embed one or more parameters in the new credential.

4.7.1 Generating a First Credential

Intermediary computer **230** may not have an old credential to validate. For example, when a browser, such as browser **295**, requests a page and/or credential from intermediary computer **230** for the first time, browser **295** may not have an old credential for intermediary computer **230** to validate. If intermediary computer **230** receives a request for a new credential without an old credential to validate, then intermediary computer **230** may generate a credential as discussed in detail herein. Additionally, the credential may be an "initialization credential", which may be used by the browser, and/or the credential-morphing-instructions, to request a new valid credential

If intermediary computer **230** receives a request from browser **295** for a new credential with an initialization credential and determines the initialization credential is valid, then intermediary computer **230** may respond with a valid new credential as discussed herein. However, if intermediary computer **230** receives a request from browser **295** for a web page from web infrastructure **205** with an initialization credential, then control may pass to step **480**.

In an embodiment, forward transformer **336** may include a credential with the credential morphing-instructions. The credential may be an initialization credential. However, in an embodiment, forward transformer **336** need not include a credential with the credential morphing-instructions.

4.8 Sending a New Credential

In step **540**, the intermediary computer may send the new credential to the client computer. For example, credential validation module **340** may send the credential to browser **295** through protocol server module **338**.

In an embodiment, credential validation module **340** may send the new credential to forward transformer **336**. Forward transformer **336** may generate one or more new credential-morphing-instructions which when executed operate on the credential and/or request a new credential. For example, if executed, the one or more instructions may be configured to replace the previous credential in memory on the client computer. Additionally or alternatively, if executed, the one or more instructions may be configured to indicate when the client computer and/or browser should send a new request for a new credential. Additionally or alternatively, if executed, the one or more instructions may be configured to generate a new credential.

4.8.1 Sending a Seed Value from which the New Credential May be Generated

Forward transformer may generate a seed value from a new credential generated by credential validation module, which may be used to generate the new credential by the client computer. FIG. **6** illustrates a process for generating a seed value and sending the seed value to the client computer to generate one or more new credentials in an example embodiment. In step **610**, the intermediary computer **230** generates a seed. For purposes of illustrating a clear example, assume forward transformer **336** receives a new credential from credential validation module **340** to be sent to a browser. Forward transformer **336** may generate a seed value based on the new credential.

In step **620**, the intermediary computer sends the seed value to the client computer. For example, forward transformer **336** sends the seed value to browser **295**.

In step **630**, the client computer generates a new credential based on the seed or a previous credential. For example, browser **295** may execute one or more credential-morphing-instructions, which may be configured to generate a valid credential based on a seed received from intermediary computer **230**. In an embodiment, over time, browser **295** may execute the credential-morphing-instructions again to generate a new valid credential based on one or more previously generated valid credentials.

4.9 Updating a Credential Over Time

The intermediary computer may repeat steps **450** according to the credential-morphing-instructions. For example, the credential morphing-instructions may define a time period, after which a browser should request, receive, generate, and/or update a new credential as discussed in detail herein.

Forward transformer **336** may render and send one or more new credential morphing-instructions with each credential and/or a seed, which if executed, may be configured to cause the client computer and/or browser to request and/or generate a new credential. The one or more new credential-morphing-instructions may be different than one or more previously sent credential-morphing-instructions.

4.10 Validating a Request for Data

Returning now to FIG. **4**, in step **460**, the intermediary intercepts a request for data. For example, protocol server module **338** may receive a request from browser **295** for data and/or instructions, such as a web page, from web infrastructure **205**.

In step **470**, the intermediary computer determines whether the request is valid by determining if the credential included in the request, if any, is valid. For example, protocol server module **338** may forward the request to credential validation module **340**. Credential validation module **340** may determine whether the credential is valid based on one or more of the methods discussed herein. If credential validation module **340** determines the credential is valid, then control passes to step **490**. Otherwise, control passes to step **480**. If credential validation module **340** determines that the request does not include a credential, then control may pass to step **480**. If credential validation module **340** determines that the request for data includes an initializing credential, then control may pass to step **480**.

If configuration **232** includes data indicating that the data requested is public, such as a home page of a web site, then credential validation module **340** may determine that the request is valid, even though the request did not include a credential. In response, control may pass to step **490**. If, however, configuration **232** includes data indicating that the data requested is public, but the request includes an invalid credential, then control may pass to step **480**.

4.11 Performing a Negative Responsive Action

In step **480**, the intermediary computer performs a negative responsive action. For example, credential validation module **340** may terminate the request. Additionally or alternatively, credential validation module **340** may treat the request as a request for an initializing credential, and in response, generate and send the initializing credential and/or seed value to browser **295** via forward transformer **336**, as discussed herein in detail. Additionally or alternatively, the intermediary computer **230** may respond with a message defined by a user and/or administrator through a client computer and/or the intermediary computer. Additionally or alternatively, intermediary computer **230** may respond with one or more standard and/or proprietary error codes and/or messages. For example, intermediary computer may return HTTP error code **400** and a message "Bad Request" to browser **295** and/or client computer **299**.

4.12 Forwarding the Request to a Server Computer

In step **490**, the intermediary computer forwards the request for data to the server computer. For example, credential validation module **340** may pass the request to reverse transformer **342**. Reverse transformer **342** may strip out data relating to the credential and produce a new request which would have been generated by browser **295** had the original instructions been received by browser **295**. Reverse transformer **342** may send the new request to web infrastructure **205** through protocol client module **332**.

If web infrastructure **205** responds to a forwarded request with data and/or instructions, then intermediary computer **230** may repeat one or more of the steps discussed herein. For example, intermediary computer **230** may perform step **410** in response to receiving the new data and/or instructions from web infrastructure **205**.

5.0 Process Overview—Dynamic Polymorphism for Script Code

Embodiments provide numerous improvements over the general idea of transforming a web page with obfuscation or polymorphism to inhibit attacks. In an embodiment, a web security device or service, which is logically positioned between web clients and a web server, applies dynamic polymorphism to original web content. In an embodiment, vulnerable HTML components of a web page are transformed before delivery to web clients, and the web page is modified in a way that causes further transformations in the HTML component after the web page is received at web client and during use or display at the web clients. Using these techniques, when the same web page is accessed by a single client, during the entire time in which the web page is in memory and used or displayed at the client, web content of that page may change one or more times. The nature and frequency of the change may vary for different client accesses to the same web page.

In one improvement, the dynamic polymorphism disclosed herein does not directly change the HTML source code of the original web page. Instead, an improved computer security device as described herein is configured to inject obfuscated script code into the web page after the web page is formed by the web server and before the web page is delivered to a web client. The injected script code is configured, when executed by the browser hosted at the client computer, to dynamically apply one or more changes to the web page before or at the same time that the web page is rendered and/or displayed using the browser. If the web page is viewed using the client browser, the HTML source code will show its original values, and the rendered web components will change value multiple times over time. The polymorphism disclosed herein is termed "dynamic" based upon the repeated periodic changes in the content of web components that may occur over time.

The improved techniques disclosed herein can significantly increase the complexity involved for adversaries to analyze the modified web page, and therefore the security of the browser, client computer and web server are increased.

5.1 Example Computing Topology

FIG. **8** illustrates a client-server computer system supporting dynamic polymorphism in script code, and with which an embodiment may be used. FIG. **8** illustrates a an electronic document before and after processing using an improved security device that is configured to modify an electronic document received from a web server by injecting script code according to an embodiment.

In an embodiment, a web server **802** generates an electronic document **804** under the control of a server-side application program or other facility, and the electronic document is communicated through one or more networks to a client computer **808** or other web client. Typically the electronic document **804** comprises a web page that includes HTML source code. Further, typically the client computer **808** hosts or executes a browser program **809** that is configured to or capable of interpreting script code as part of loading, rendering and causing display of the electronic document on a computer display device associated with the client computer **808**. An example of script code is JAVASCRIPT and examples of browser program **809** are APPLE SAFARI, MOZILLA FIREFOX, GOOGLE CHROME, MICROSOFT INTERNET EXPLORER, and others.

Security device **806** is logically positioned between the web server **802** and a client computer **808**. In some embodiments, security device **806** may be implemented in the manner of intermediary computer **230** as described above. In various embodiments, security device **806** may be implemented using a special-purpose computer or computing appliance that is located near the web server **802**; for example, security device **806** may be co-located in the same data center as the web server. In another embodiment, the security device **806** may be implemented as a service that is accessible over computer networks using application, program or function calls, inter-process messaging, or other mechanisms of inter-computer communication. For example, the security device **806** may comprise one or more computer programs or other software elements that are

hosted in one or more instances of computing resources of a cloud computing facility. In various embodiments, the cloud computing facility may be a private cloud facility that is associated with an owner or operator of the web server **802**, or a public cloud facility, or a cloud facility of a service provider that is different than an owner or operator of the web server **802**.

In various embodiments, the techniques herein may be implemented using a special-purpose computer, a specially configured network infrastructure element such as a router, switch or firewall, or a set of computer programs hosted in a data center or cloud computing facility and implemented as a service that can be called from the web server **802** or another element.

In the arrangement of FIG. **8**, the security device **806** receives all electronic documents that the web server **802** generates, before the documents are delivered over one or more networks to the client computer **808**. For example, electronic document **804** is received at the security device **806**. In response to receiving the electronic document **804**, the security device **806** modifies the HTML source code **810** of the document to inject or include a set of new script code **820**, resulting in creating a modified electronic document **814**. The security device **806** then forwards the modified electronic document **814** into the network(s) toward the client computer **808**.

In an embodiment, security computer **806** comprises script analysis logic **812** and script injection logic, and is coupled to a file **822** comprising stored script code for injection. In an embodiment, the script analysis logic **812** is configured to examine an electronic document **804** and source code **810** within the electronic document and identify a location in which new special-purpose script code **820** in file **802** may be inserted or injected. As further described herein, the script analysis logic **812** also may be configured to modify the file **822** of stored script code for injection from time to time. In an embodiment, the script injection logic is configured to place a copy of the stored script code from the file **822** in the electronic document to result in producing a modified electronic document **814** in which the script code has been injected.

The new script code **820** is configured to execute automatically at the client computer **808** when a browser at the client computer loads the modified electronic document **814**. For example, the HTML expression <body onload="script( );"> may form a part of the new script code **812**, or an expression such as window.onload=function . . . may be used. Other HTML tags or other coding may be used in the new script code **812**, provided that the new script code is configured to execute automatically on the client computer **808** promptly after the electronic document **804** is initially loaded.

Synchronization of the security device **806** and the browser at the client computer **808** may be performed in a manner similar to that described above for intermediary computer **230**. In the previous description, a keep-alive value stays synchronized between the client browser and the intermediary computer **230**; the keep-alive value is synchronized by the client-side browser frequently sending the current keep-alive value to the intermediary computer **230** in exchange for a new keep-alive value. The credential validation module **340** and forward transformer **336** work in concert to validate the current keep-alive value and generate the next keep-alive value. In the approach of FIG. **8**, the security device **806** may stay in sync with changes to the client-side JavaScript; for example, credential validation logic **340** and forward transformer logic **336** may operate in concert to validate the modified DOM elements on the client-side.

5.2 Example Process Flow

FIG. **9** illustrates a computer-implemented process of using dynamic polymorphism to improve resistance to attacks embodied in script code.

At block **902**, at a security computer that is logically interposed between a server computer that generates electronic documents and a client computer that is capable of executing script code in the electronic documents, the process obtains a particular electronic document that contains source code with values for transformation or obfuscation. In some cases, the process obtains the particular electronic document because the browser program **809** of the web client **808** has requested the original electronic document **804** from the web server **802**, for example, using an HTTP request for a particular static or dynamic HTML document. The process may obtain the particular electronic document programmatically, using the interception techniques that have been described herein for intermediary computer **230**.

At block **904**, the process loads or obtains script code that is configured to cause polymorphic transformation of source code of electronic documents and is configured to run upon loading. For example, security computer **806** loads a copy of the stored script code **802** from file **822**. Program instructions in an application program running in security computer **806** may include disk file retrieval operations to accomplish the loading.

As seen at block **910**, optionally, the script code may be configured for dynamic modification of element values. Dynamic modification of element values, in this context, means that the script code causes a different change to element values in the particular electronic document at different times after that script code is loaded and interpreted or executed as part of rendering the particular electronic document.

At block **906**, the process modifies the particular electronic document by inserting the script code into the electronic document, resulting in producing a modified copy of the particular electronic document. Any of various insertion techniques may be used. For example, the application program running on security computer **806** may create headers for a new well-formed HTTP response in main memory, then write in the script code to the same memory area, then write in the script code, then write in ending tags to complete the well-formed response.

At block **908**, the process provides the modified electronic document to the client computer in response to a request for the original electronic document. For example, block **908** may involve the security computer **806** generating and sending the well-formed HTTP response to the web client **808** on behalf of the web server **802**, using HTTP server code.

In an embodiment, the new script code **812** is configured to cause, when executing in the browser of the client computer **808**, one or more changes in HTML form attributes of the source code **810** of the electronic document **804** that has been loaded into memory of the browser. In one embodiment, the new script code **812** comprises JAVASCRIPT that is configured to search within HTML code in memory of the browser for name-value pairs within INPUT tags of the HTML code and to identify the position of the value, for example by calling HTML DOM method "getElementById( )". When a value is found, the bytes between the quote mark characters are deleted and the same memory is modified to substitute the output of a pseudo-random generator. This algorithm continues until all the HTML code has been inspected or scanned and modified.

Using this approach, if a user invokes the VIEW SOURCE function of the browser, the original untransformed web page is displayed. TABLE 1 illustrates an example of VIEW SOURCE output for a hypothetical web page, with dynamic polymorphism in effect. However, if the user invokes the INSPECT ELEMENT function of the browser, the transformed web page after modification by the new script code **812** is displayed. TABLE 2 illustrates an example of INSPECT ELEMENT output for a hypothetical web page.

TABLE 1

Example VIEW SOURCE Output for Hypothetical Web Page
<fieldest form=”sign_in_form”>
<div>
<label for=”username”>
Enter your username:
</label>
[<input type= “text” id= “username” name= “username” value=]
“”
[maxlength= “50” size = “20” autofocus />]
<span class = “nodisplay”>
Please enter a username.
</span>
</div>
<div>

TABLE 2

Example INSPECT ELEMENT Output for Hypothetical Web Page
<div id= “login” class= “ent-grid drop-shadow”>
::before
<div class “col-1-2 west”>
<form id= “sign-in-form” name= “sign_in_form” method= “POST”
action= “ /
“application/x-www-form-urlencoded”>
<fieldset form= “sign_in_form>
<div>
<label for= “username”>
Enter your username:
</label>
<span class= “missing”>Please enter a username.</span>
</div>
<div> </div>
<div id=“remember”>...</div>
<p>...</p>

This approach provides numerous improvements over the general idea of modifying a web page to obfuscate its content or confuse an analyst or a bot. For example, because the HTML page source is not changed, attackers that only analyze the HTML page source code will not know that the countermeasure described herein has been implemented. For attackers that analyze the Document Object Model (DOM), for example, using INSPECT ELEMENT, the conflicting contents of the output from VIEW SOURCE and INSPECT ELEMENT will require investigation. Even if this investigation results in identifying the presence of the new script code **812**, that code will appear in obfuscated form. Understanding the total content of the HTML source code, INSPECT ELEMENT output, and script code **812** will require extensive and difficult reverse engineering effort.

From Table 2, it will be apparent that the injected script code has changed the values of certain elements of the HTML elements in the electronic document. For example, the element with id="username" has been transformed to id="m7x8faxuyt", and the element with name="username" has been transformed to name="eiu9tzvb7r". To perform such a transformation, the injected script code includes the obfuscated values "m7xfaxuyt" and "eiu9tzvb7r" as coded variables or constants. The obfuscated values may be generated using a random number generator or pseudo-random number generator within an application program in the security device **206** that implements FIG. **9**. Both the injected script code that is delivered to the browser, and the application program on the security device **206**, may implement symmetric transformation operations and may include a seed value, which can be carried in the clear in the script code, so that clock synchronization or a protocol such as NTP are not required to synchronize the browser and server and permit transformation of an obfuscated element value back into a clear source value.

In an embodiment, any one or more of the obfuscated values may be carried in the injected script code in segments that are reassembled and used by the script code when it executes in the browser. For example, the value "m7xfaxuyt" can be segmented in the injected script code using three (3) segments that are combined into a final value at runtime using the code snippet shown in TABLE 3.

TABLE 3

SEGMENTED OBFUSCATION CONSTANT VALUES

```
var s1 = "m7";
var s2 = "x8fax"
var s3 = "uyt"
var final = s1 + s2 + s3;
```

In various embodiments, the number of segments may be different, and the length of each segment may vary. The number of segments that are used, and the length of each segment, may change in a pseudo-random manner from page to page. For example, in the page excerpt shown in TABLE 1, TABLE 2, the value may be split into three (3) variables and the next time it may be split into four (4) or five (5). The use of variable segmentation in this manner is expected to increase the time and cost involved in reverse engineering the resulting electronic document and the injected script code.

In one embodiment, a file **822** containing the injected script code is stored at the security computer **806** or in a location that the security computer can access. In one embodiment, the file **822** is static and used for all different electronic documents **804** that the web server **802** generates or that the security computer **806** processes. In another embodiment, the contents of the file **822** may change over time so that different script code is injected into the electronic documents at different times; a control path from script analysis logic **812** to stored script code file **822** is shown in FIG. **8** for this purpose. Thus, the script analysis logic **812** may be configured to modify the file **822** from time to time to change the contents of the script code to be injected; the changes may include different numbers or lengths of segments of the type shown in TABLE 3, or may include completely different obfuscation approaches or techniques other than the use of segmented constants or variables. Therefore, the script code file **822** may adapt, over time, to changing attack modes or to new concepts of the best practices that are appropriate to use to thwart attacks.

In an embodiment, the script code to be injected, in file **822**, is configured for periodic execution, for example using JAVASCRIPT repeat function calls that cause the browser to perform repeated periodic execution of all or a part of the script code. In an embodiment, the periodic execution capability is used to further change the protected HTML form attributes, after the initial change that occurs when the modified electronic document **814** is loaded in the browser and executed. As an example, the script code may be configured to perform the changes to the modified electronic document, for one particular HTML element, which are shown in TABLE 4.

TABLE 4

RESULTS OF PERIODIC REPEATED CODE EXECUTION

Time	Element ID	Element Name
(Original electronic document 804)	"username"	"username"
(Modified electronic document 814 as loaded)	"m7x8faxuyt"	"eiu9tzvb7r"
1 second after loaded	"x8faxuytm7"	"tzvb7reiu9"
2 seconds after loaded	"uytm7x8fax"	"zvb7reiu9t"

TABLE 5 provides an example of pseudo script code that could be injected on a HTML page with one form field element. The injected code, specifically the transform function will transform the HTML form field element name and ID ("username") after the page is loaded, and continue to transform it every 1 second, within the first 2 seconds. A "set interval" function can be used to instruct the client browser to execute the transform function every second. The pseudo script code also uses obfuscated transformation values using the string concatenation method described above; this is just one of many obfuscation techniques the security device can apply. The function name and variable names can also be obfuscated to difficult-to-read values. This pseudo script code will cause the "username" to change in the way specified in Table 4.

TABLE 5

EXAMPLE INJECTED CODE

```
variable declarations:
transform names = ["a1", "a2", "a3"];
transform ids = ["i1", "i2", "i3"];
current id = "username";
s1 = "m7";
s2 = "x8fax";
s3 = "uyt";
t1 = "eiu9";
t2 = "t";
t3 = "zvb7r";
first id transform = s1+s2+s3;
first name transform = t1+t2+t3;
(other declarations of other id transforms and name transforms
up to the maximum allowed value of the index value i below)
transform function declaration:
let elem = the element of the document that matches the "current
id"
for a number of times indicated in an index value i,
    let element id = the ith id transform;
    let current id = the ith transform ids;
    let element name = the ith name transform;
    increment i;
repeat.
include an 'execute on load' script instruction
include a method to post the transformed value to the server
when the element matching the current id is submitted by the
user
call the transform function every 1 seconds
```

TABLE 7 below presents another example on the same HTML form field. In the example of TABLE 7, the transform function is modified to cause changing the form field name and ID for as long as the code runs, every 1 second. The transform function shifts the name and ID string values by one character every time it is called. It will result in the sequence specified in TABLE 6.

TABLE 6

RESULTS OF PERIODIC REPEATED CODE EXECUTION

Time	Element ID	Element Name
(Original electronic document 804)	"username"	"username"
(Modified electronic document 814 as loaded)	"abcdefghi"	"123456789"
1 second after loaded	"iabcdefgh"	"234567891"
2 seconds after loaded	"hiabcdefg"	"345678912"
3 seconds after loaded	"ghiabcdef"	"456789123"
. . .	. . .	. . .

TABLE 7

EXAMPLE INJECTED CODE

```
variable declarations:
current id = "username";
transform name = "123456789";
transform id = "abcdefghi";
transform function declaration:
let elem = the element of the document that matches the "current
id"
   let element-id be the transform id;
   let current-id be the transform id;
   let elem-name be the transform name;
   let the transform name be a concatenation of substring (1,8)
of the transform name and substring (0,1) of the transform name;
   let the transform id be a concatenation of the substring
(8,1) of the transform id and substring (0,8) of the transform
id;
include an 'execute on load' script instruction
include a method to post the transformed value to the server
when the element matching the current id is submitted by the
user
call the transform function every 1 seconds
```

In various embodiments, any of the specific transformed values shown under CONTENT in TABLE 4 may be further obfuscated or hidden in the script code using other techniques.

The values shown under CONTENT in TABLE 4 can be based upon the initial transformed value, for example "m7x8faxuyt" as shown, using a pseudo-random generating algorithm implemented in software code in the security device **806**, or using special-purpose digital logic that is also configured to perform pseudo-random number generation. The time interval between modifications is shown, in TABLE 4 as an example, as a consistent or monotonically increasing value of 1 second. In other embodiments, the time interval may be other than 1 second. Because the security device **806** controls the modification of the file **822** that contains the script code to be injected, the security device necessarily has the time interval stored or available. When the time interval is relatively large, such as whole integer values of seconds, to validate the transformed values shown under CONTENT in TABLE 4 or other transformed values, the processes herein do not require precise clock synchronization with the client computer **808**.

Because all the details of the transformation are carried on the modified electronic document **814**, the security computer **806** does not need state information to apply a reverse transformation.

The original electronic document **804** may include values indicating whether static polymorphism is used to protect the page or whether dynamic polymorphism as described herein is used. In an embodiment, the security computer **806** implements both static polymorphism and dynamic polymorphism as described herein. Values that the web server **802** embeds in the original electronic document **804** may signal or instruct the security **806** to perform either static polymorphism or dynamic polymorphism on each electronic document that the web server **802** emits that is received at the security device.

The process described for FIG. **9** may be implemented, in various embodiments, using any of a variety of procedural or object-oriented programming languages. For example, JAVA programming can be used to implement the logic of FIG. **9**. The script code that is loaded at block **904** may be JAVASCRIPT or another form of script; that code may comprise a code snippet that can be inserted into HTML source code that the server computer outputs using a concatenation, merge, or file rewriting operation implemented using JAVA.

6.0 Implementation Mechanisms—Hardware Overview

According to one embodiment, the techniques described herein are implemented by one or more special-purpose computing devices. The special-purpose computing devices may be hard-wired to perform the techniques, or may include digital electronic devices such as one or more application-specific integrated circuits (ASICs) or field programmable gate arrays (FPGAs) that are persistently programmed to perform the techniques, or may include one or more general purpose hardware processors programmed to perform the techniques pursuant to program instructions in firmware, memory, other storage, or a combination. Such special-purpose computing devices may also combine custom hard-wired logic, ASICs, or FPGAs with custom programming to accomplish the techniques. The special-purpose computing devices may be desktop computer systems, portable computer systems, handheld devices, networking devices or any other device that incorporates hard-wired and/or program logic to implement the techniques.

For example, FIG. **7** is a block diagram that illustrates a computer system **700** upon which an embodiment of the invention may be implemented. Computer system **700** includes a bus **702** or other communication mechanism for communicating information, and a hardware processor **704** coupled with bus **702** for processing information. Hardware processor **704** may be, for example, a general purpose microprocessor.

Computer system **700** also includes a main memory **706**, such as a random access memory (RAM) or other dynamic storage device, coupled to bus **702** for storing information and instructions to be executed by processor **704**. Main memory **706** also may be used for storing temporary variables or other intermediate information during execution of instructions to be executed by processor **704**. Such instructions, when stored in non-transitory storage media accessible to processor **704**, render computer system **700** into a special-purpose machine that is customized to perform the operations specified in the instructions.

Computer system **700** further includes a read only memory (ROM) **708** or other static storage device coupled to bus **702** for storing static information and instructions for processor **704**. A storage device **710**, such as a magnetic disk or optical disk, is provided and coupled to bus **702** for storing information and instructions.

Computer system **700** may be coupled via bus **702** to a display **712**, such as a cathode ray tube (CRT), for displaying information to a computer user. An input device **714**, including alphanumeric and other keys, is coupled to bus **702** for communicating information and command selections to processor **704**. Another type of user input device is cursor control **716**, such as a mouse, a trackball, or cursor direction keys for communicating direction information and command selections to processor **704** and for controlling cursor movement on display **712**. This input device typically has two degrees of freedom in two axes, a first axis (e.g., x) and a second axis (e.g., y), that allows the device to specify positions in a plane.

Computer system **700** may implement the techniques described herein using customized hard-wired logic, one or more ASICs or FPGAs, firmware and/or program logic which in combination with the computer system causes or programs computer system **700** to be a special-purpose machine. According to one embodiment, the techniques herein are performed by computer system **700** in response to processor **704** executing one or more sequences of one or more instructions contained in main memory **706**. Such instructions may be read into main memory **706** from another storage medium, such as storage device **710**. Execution of the sequences of instructions contained in main memory **706** causes processor **704** to perform the process steps described herein. In alternative embodiments, hard-wired circuitry may be used in place of or in combination with software instructions.

The term "storage media" as used herein refers to any non-transitory media that store data and/or instructions that cause a machine to operation in a specific fashion. Such storage media may comprise non-volatile media and/or volatile media. Non-volatile media includes, for example, optical or magnetic disks, such as storage device **710**. Volatile media includes dynamic memory, such as main memory **706**. Common forms of storage media include, for example, a floppy disk, a flexible disk, hard disk, solid state drive, magnetic tape, or any other magnetic data storage medium, a CD-ROM, any other optical data storage medium, any physical medium with patterns of holes, a RAM, a PROM, and EPROM, a FLASH-EPROM, NVRAM, any other memory chip or cartridge.

Storage media is distinct from but may be used in conjunction with transmission media. Transmission media participates in transferring information between storage media. For example, transmission media includes coaxial cables, copper wire and fiber optics, including the wires that comprise bus **702**. Transmission media can also take the form of acoustic or light waves, such as those generated during radio-wave and infra-red data communications.

Various forms of media may be involved in carrying one or more sequences of one or more instructions to processor **704** for execution. For example, the instructions may initially be carried on a magnetic disk or solid state drive of a remote computer. The remote computer can load the instructions into its dynamic memory and send the instructions over a telephone line using a modem. A modem local to computer system **700** can receive the data on the telephone line and use an infra-red transmitter to convert the data to an infra-red signal. An infra-red detector can receive the data carried in the infra-red signal and appropriate circuitry can place the data on bus **702**. Bus **702** carries the data to main memory **706**, from which processor **704** retrieves and executes the instructions. The instructions received by main memory **706** may optionally be stored on storage device **710** either before or after execution by processor **704**.

Computer system **700** also includes a communication interface **718** coupled to bus **702**. Communication interface **718** provides a two-way data communication coupling to a network link **720** that is connected to a local network **722**. For example, communication interface **718** may be an integrated services digital network (ISDN) card, cable modem, satellite modem, or a modem to provide a data communication connection to a corresponding type of telephone line. As another example, communication interface **718** may be a local area network (LAN) card to provide a data communication connection to a compatible LAN. Wireless links may also be implemented. In any such implementation, communication interface **718** sends and receives electrical, electromagnetic or optical signals that carry digital data streams representing various types of information.

Network link **720** typically provides data communication through one or more networks to other data devices. For example, network link **720** may provide a connection through local network **722** to a host computer **724** or to data equipment operated by an Internet Service Provider (ISP) **726**. ISP **726** in turn provides data communication services through the world wide packet data communication network now commonly referred to as the "Internet" **728**. Local network **722** and Internet **728** both use electrical, electromagnetic or optical signals that carry digital data streams. The signals through the various networks and the signals on network link **720** and through communication interface **718**, which carry the digital data to and from computer system **700**, are example forms of transmission media.

Computer system **700** can send messages and receive data, including program code, through the network(s), network link **720** and communication interface **718**. In the Internet example, a server **730** might transmit a requested code for an application program through Internet **728**, ISP **726**, local network **722** and communication interface **718**.

The received code may be executed by processor **704** as it is received, and/or stored in storage device **710**, or other non-volatile storage for later execution.

7.0 Other Aspects of Disclosure

Using the networked computer arrangements, intermediary computer, and/or processing methods described herein, security in client-server data processing may be significantly increased. Dynamic credential techniques discussed herein effectively reduce automated attacks. Consequently, one or more various attacks, such as a denial of service ("DOS") attack, credential stuffing, fake account creation, ratings or results manipulation, man in the browser attacks, reserving rival goods or services, scanning for vulnerabilities, and/or exploitation of vulnerabilities, are frustrated because requests are accompanied by a credential that changes over time.

In the foregoing specification, embodiments of the invention have been described with reference to numerous specific details that may vary from implementation to implementation. The specification and drawings are, accordingly, to be regarded in an illustrative rather than a restrictive sense. The sole and exclusive indicator of the scope of the invention, and what is intended by the applicants to be the scope of the invention, is the literal and equivalent scope of the set of claims that issue from this application, in the specific form in which such claims issue, including any subsequent correction.

What is claimed is:

1. A data processing system configured to improve resistance of a client computer to attacks and comprising:

one or more hardware processors;

script analysis logic coupled to the one or more processors and configured to obtain a particular electronic document from a server computer;

script injection logic coupled to the one or more processors and configured to insert a set of script code into source code of the electronic document to result in producing a modified electronic document prior to providing the modified electronic document to a client computer;

wherein the script code is configured to:

improve resistance of the client computer to attacks by running upon loading in the client computer and to cause transforming, when running in the client computer, one or more values of one or more elements of the source code of the electronic document into obfuscated values of the one or more elements,

repeatedly periodically execute in the client computer after loading in the client computer, and

cause the transforming in a different manner at each time that the script code repeatedly periodically executes in the client computer.

2. The data processing system of claim **1**, wherein the script code is configured to cause the transforming using a pseudo-random transformation of the values of the elements.

3. The data processing system of claim **1**, wherein the script code comprises two or more segments of a particular obfuscated value, and wherein the script code is configured to cause transforming a particular value of a particular element of the source code into a particular combination of the two or more segments.

4. The data processing system of claim **3**, wherein the script code is configured to cause transforming the particular value of the particular element of the source code into a pseudo-randomly selected combination of the two or more segments.

5. The data processing system of claim **3**, wherein the script code is configured to cause transforming the particular value of the particular element of the source code into a randomly selected combination of the two or more segments.

6. The data processing system of claim **1**, wherein the script code is configured to repeatedly periodically execute in the client computer at time intervals specified using a time interval value in the script code, and wherein the script injection logic is configured to periodically update the time interval value in the script code to a different time interval value.

7. The data processing system of claim **1**, wherein the script code comprises JAVASCRIPT script code.

8. A data processing method of improving resistance of a client computer to attacks comprising:

at an intermediary computer:

obtaining a particular electronic document from a server computer;

inserting a set of script code into source code of the electronic document to result in producing a modified electronic document;

providing the modified electronic document to a client computer;

wherein the script code is configured to:

improve resistance of the client computer to attacks by running upon loading in the client computer and to cause transforming, when running in the client computer, one or more values of one or more elements of the source code of the electronic document into obfuscated values of the one or more elements,

repeatedly periodically execute in the client computer after loading in the client computer, and

cause the transforming in a different manner at each time that the script code repeatedly executes in the client computer.

9. The data processing method of claim **8**, wherein the script code is configured to cause the transforming using a pseudo-random transformation of the values of the elements.

10. The data processing method of claim **8**, wherein the script code comprises two or more segments of a particular obfuscated value, and wherein the script code is configured to cause transforming a particular value of a particular element of the source code into a particular combination of the two or more segments.

11. The data processing method of claim **10**, wherein the script code is configured to cause transforming the particular value of the particular element of the source code into a pseudo-randomly selected combination of the two or more segments.

12. The data processing method of claim **10**, wherein the script code is configured to cause transforming the particular value of the particular element of the source code into a randomly selected combination of the two or more segments.

13. The data processing method of claim **8**, wherein the script code is configured to repeatedly periodically execute in the client computer at time intervals specified using a time interval value in the script code, and further comprising periodically updating the time interval value in the script code to a different time interval value.

14. The data processing method of claim **8**, wherein the script code comprises JAVASCRIPT script code.

15. A data processing method of improving resistance of a client computer to attacks comprising:

using a security computer that is logically interposed between a server computer that generates HTML documents and a client computer, obtaining a HTML electronic document from the server computer;

inserting a set of JAVASCRIPT script code into HTML source code of the HTML document to result in producing a modified HTML document;

providing the modified HTML document to the client computer;

wherein the JAVASCRIPT code is configured to:

improve resistance of the client computer to attacks by running upon loading in the client computer and to cause transforming, when running in the client computer, one or more values of one or more elements of the HTML source code of the HTML document into obfuscated values of the one or more elements,

repeatedly periodically execute in the client computer at time intervals specified using a time interval value in the JAVASCRIPT code after loading in the client computer, and

periodically updating the time interval value in the JAVASCRIPT code to a different time interval value.

16. The data processing method of claim **15**, wherein the JAVASCRIPT code is configured to cause the transforming using a pseudo-random transformation of the values of the elements.

17. The data processing method of claim **15**, wherein the JAVASCRIPT code comprises two or more segments of a particular obfuscated value, and wherein the JAVASCRIPT code is configured to cause transforming a particular value of a particular element of the HTML source code into a particular combination of the two or more segments.

18. The data processing method of claim **17**, wherein the JAVASCRIPT code is configured to cause transforming the particular value of the particular element of the HTML source code into a pseudo-randomly selected combination of the two or more segments.

19. The data processing method of claim **17**, wherein the JAVASCRIPT code is configured to cause transforming the particular value of the particular element of the HTML source code into a randomly selected combination of the two or more segments.

20. The data processing method of claim **15**, wherein the JAVASCRIPT code is configured to repeatedly periodically execute in the client computer, and wherein the JAVASCRIPT code is configured to cause the transforming in a different manner at each time that the JAVASCRIPT code repeatedly periodically executes in the client computer.

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